A Comparative Study on Fecal Sludge Management in Three Municipalities of Bangladesh

by

(**Md.Sahidul Islam**)

A Thesis submitted in Partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering

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A Comparative Study on Fecal Sludge Management in Three Municipalities of Bangladesh

A thesis report submitted to the Department of Civil Engineering in Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh in partial fulfillment of the requirements for the degree of

"Master of Science in Civil Engineering"

Supervised by:
Dr. Khondoker Mahbub Hassan
Professor
Department of Civil Engineering
KUET, Khulna – 9203

Prepared by:
Md. Sahidul Islam
Roll No: 1201502
Department of Civil Engineering
KUET, Khulna – 9203

Department of Civil Engineering
Khulna University of Engineering & Technology
Khulna - 9203, Bangladesh
October, 2016

Declaration

This is to certify that the thesis work entitled "*A Comparative Study on Fecal Sludge Management in Three Municipalities of Bangladesh*" has been carried out by *Md. Sahidul Islam* in the Department of *Civil Engineering*, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

Dr. Khondoker Mahbub Hassan
(Supervisor)
Professor
Department of Civil Engineering
KUET, Khulna - 9203

Md. Sahidul Islam
Roll No: 1201502

Approval

This is to certify that the thesis work submitted by Md. Sahidul Islam entitled "*A Comparative Study on Fecal Sludge Management in Three Municipalities of Bangladesh*" has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering in the Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh on 5 October, 2016.

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   Professor
   Bangladesh University of Engineering and Technology
   Dhaka-1000, Bangladesh

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Abstract

The sanitation needs of 2.7 billion people worldwide are served by onsite sanitation technologies, and that number is expected to grow to 5 billion by 2030. Bangladesh provides a striking example of progress to meet the Millennium Development Goal (MDG) - 7 to halve, by 2015, the "proportion of urban population with access to improved sanitation". Open defecation has been reduced to only 1%, a milestone change from 42% in 2003. But the increase in fixed-place defecation has created an urgent need for Fecal Sludge Management (FSM) in the cities of Bangladesh, where most human waste is dumped untreated into waterways or onto marginal land, harming the health of the country's poorest. The draft national regulatory framework identifies municipalities as responsible for FSM.

This research was carried out in Khulna City Corporation, Kushtia Municipality and Jhenaidah Municipality. The study involved data collection, field visits, fecal sludge sampling and laboratory analysis, investigation on emptying, treatment and disposal services.

Khulna City Corporation (KCC) covers an area of 45.65 km^2 with tax-payee holdings of 66,257 of population 15,00,689. Manual sweepers are providing emptying services. KCC is providing both manual (by boggy) and mechanical emptying (vacutug) services since ten years. But there was no designated disposal site and the septage/fecal sludge was disposed here and there specially in drains which ultimately flows to river. 84% of the septic tanks have no soak wells and is connected directly to drains. Besides, City Corporation, Community Development Committee (CDC) have three smaller ($1m^3$) vacutugs and those are much popular in services. Annual fecal sludge generation was estimated to be around 7,10,000 m^3. Recently, KCC has started to construct a fecal sludge treatment plant (FTP) with financial assistance from Bill & Melinda Gates Foundation (BMGF).

Kushtia Municipality is a class "A" municipality and recently been extended to total land area of 42.79 sq.km with population 3,75,149. In this municipality, 68% septic tanks have no soak well and are connected to drains. Fecal sludge generation was estimated to be around 104,581 m^3/year. In this municipality, vacutug services have been launched since ten years. They have a treatment plant with two drying beds and coco-peat filter and compost is being produced here. Recently, the emptying demand has been increased tremendously, but capacity of the treatment plant is less. Thus, another FTP is under planning to meet the additional demands for FSM.

Jhenaidah municipality is a small town of 32.42 Sq.km with 1,57,822 population. About 80% of the septic tanks have soak wells. Annual fecal sludge (FS) generation was estimated to be around 58,705 m^3. A constructed wetland was built by the Department of Public Health Engineering (DPHE) in 2012 and handed over to the municipality for field operation and maintenance (O & M) using two vacutugs. But the municipality didn't have any experience for the O & M of those and eventually left unused.

Characterization of FS has been done for three municipalities. Experiments have been performed for sixteen wastewater quality parameters for each FS sample such as solids concentration, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), nutrients, pathogens, etc. The Solid contents in Fecal Sludge of these three towns varied between 3% to 6%. The range of COD concentrations were 7600-9600 mg/L. BOD_5 concentrations were 819-1662 mg/L while the acceptable limit for disposal into inland water bodies is only 40 mg/L (ECR, 1997). Thus, it's a big challenge to reduce the BOD_5 in fecal sludge treatment plant for its ultimate disposal.

Based on the entire value chain of FSM in three municipalities, proposals have been suggested for the overall improvement. There are 38.3%, 46% and 54.5% of pit toilets in Khulna, Kushtia and Jhenaidah, respectively. Placement of water seal, Y-junction of pit toilets and proper maintenance of the toilets can keep the toilets hygienic and improved. In Khulna and Kushtia municipalities, around 84% and 68% of septic tanks, respectively are connected to drains and thus stringent regulatory enforcement seemed imperative for its control and revision following Bangladesh National Building Code (BNBC). Manual emptiers can be registered by Municipal Authority so that only they can provide the services ensuring health and safety. Small devices such as Gulper and Diaphragm-Pump for emptying, Excrevator/Augur for extracting the hard solids from bottom of septic tanks, promotion and encouragement of local manufacturing process of Vacutugs, provision of secondary transfer station (STS), FSM as market based solution, simple treatment technology, raising Social Awareness, addressing Health and Safety issues, etc. have been proposed for the improvement of fecal sludge management in the study areas.

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ABBREVIATION

ADB	Asian Development Bank
ADAB	Association of Development Agencies in Bangladesh
AIT	Asian Institute of Technology
APHA-AWWA-WEF	American Public Health Association, American Water Works Association, Water Environment Federation
BMGF	Bill & Melinda Gates Foundation
BNBC	Bangladesh National Building Code
BOD	Biochemical Oxygen Demand
BORDA	Bremen Overseas Research & Development Association
BRAC	An NGO
CBO	Community Based Organization
CDC	Community Development Committee
CDD	Consortium for DEWATS Dissemination (CDD) Society
CERLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLTS	Community-led total sanitation
COD	Chemical Oxygen Demand
CW	Constructed Wetland
CWASA	Chittagong Water and Sewerage Authority
DEWATS	Decentralized Wastewater Treatment System
DHS	Demographic Health Survey
DoE	Department of Environment
DPHE	Department of Public Health Engineering
DWASA	Dhaka Water and Sewerage Authority

DWSS	Department of Water Supply And Sewerage
EAWAG	Swiss Federal Institute of Aquatic Science and Technology
E.Coli.	Escherichia Coliform
EC	Electrical Conductivity
ECR (ECA)	Environmental Conservation Rule/Act
EPA	Environmental Protection Act
FS	Faecal/Fecal Sludge
FSM	Faecal/Fecal Sludge Management
FSTP	Fecal sludge treatment plant
FTP	Fecal treatment plant
GIS	Geographic Information System
GoB	Government of Bangladesh
HRT	Hydraulic Retention Time
IGES	Institute for Global Environmental Strategies
IRC	International Reference Centre for Community Water Supply
ITN-BUET	International Training Network-Bangladesh University of Engineering and Technology
IWMI	International Water Management Institute
JMP	Joint Monitoring Programme – WHO/Unicef
KCC	Khulna City Corporation
KUET	Khulna University of Engineering and Technology
KWASA	Khulna Water Supply and Sewerage Authority
LA	Legislative Assembly
LGD	Local Government Division
LGED	Local Government Engineering Department
LGI	Local Government Institution

MAPET	Manual Pit Emptying Technology
MDG	Millennium Development Goals
MPN	most probable number
MSL	mean sea level
NGO	Non-Government Organisation
NMIP	National Management Information Project
ODF	Open-defecation free
Paurashava	Municipality
PCA	Principal Component Analysis
PPE	Personal Protective Equipment
PSU	Policy Support Unit
QIS	Qualitative Information System
SANDEC	Sanitation in Developing Countries
SNV	SNV Netherlands Development Organisation
STS	Secondary Transfer Station
TC	Total Coliform
TS	Total Solids
TSS	Total Suspended Solids
TVS	Total Volatile Solids
UNCRD	United Nations Centre for Regional Development
UNDP	United Development Programme
UNICEF	United Nations Children's Fund
UPPR	Urban Partnerships for Poverty Reduction
URP	Urban and Rural Planning
USAID	United States Agency of International Development
Vacutug	Vacuum + Truck (Tug)

VI	Volumetric Index
VIP	ventilated improved pit
VSS	Volatile Suspended Solids
WASA	Water Supply and Sewerage Authority
WASH	Waster Sanitation and Hygiene
WHO	World Health Organization
WSP	Water and Sanitation Programme
WSS	Water Supply and Sanitation
WWTP	Wastewater Treatment Plants

CHAPTER I

INTRODUCTION

1.1 Background

Bangladesh provides a striking example of progress to meet the Millennium Development Goal (MDG) - 7 to halve, by 2015, the “proportion of urban population with access to improved sanitation”. Open defecation has reduced from 42% in 2003 to 1% in 2015, though 53% of households still do not use improved sanitation (WHO/UNICEF, 2014). The 2012 Economics of Sanitation study estimated that poor sanitation and hygiene costs the economy of Bangladesh US$ 4.2 billion, equivalent to 6.3% of Gross Domestic Product (WSP, 2012). Of Bangladesh’s 46 million urban inhabitants, more than 80% use on-site sanitation (WHO/UNICEF, 2014). The national regulatory framework identifies municipalities as responsible for FSM. Bangladesh has 522 urban centers accounting for 29% (44 Million) of the national population. Thus, we are on the brink of another “sanitation revolution” to manage the human excreta.

The city-wide management of fecal sludge requires regular emptying, majority of which is done manually by marginalized communities, while mechanical emptying is limited to certain areas. Urban populations are growing very rapidly due to economic migration. Sweepers are declining in number as they are opting for safer, less stigmatized livelihoods. Currently, the costs of emptying tanks and pits are prohibitive and make customers unwilling to desludge their toilets regularly and safely. As a result, most city residents connect their tanks directly to drains and local line-agencies have been unable to regulate pollution effectively despite the detrimental effects on the environment or the public health threat (Opel, 2012).

Most of the cities in Bangladesh, including the third largest Khulna (Islam, 2012), have no designated dumping sites or treatment facilities for fecal sludge despite acute sanitation challenges owing to high population density, rapid and unplanned growth. Khulna is one of the most climate vulnerable cities in the world (Haque, 2013) having a population around 1.4 Million (KCC, 2014) has no sewer network; The household sanitation is predominantly on-site technologies, 68.4% septic tanks and 31.6% pits (Opel, 2011), which require regular emptying. But formal emptying is rare as most are directly connected to surface water drains or water bodies. The rest are mainly emptied manually by sweepers (Courilleau and Cartmell, 2010) who often do not have capacity to transport emptied sludge to a safe or designated place for disposal. Recently, Khulna City Corporation (KCC) is ought to upgrade the vacutug service considering a fair tariff for better fecal sludge management (SuSanA, 2008). On the other hand, Kushtia municipality under Khulna division has got a fecal sludge treatment plant comprising of sludge drying bed with co-composting facilities since 2012 but unable to create demand for reuse or disposal of bio-solids and therefore remains financially nonviable. Another planted wetland system for fecal sludge treatment was being built in Jhenaidah municipality in 2012 but never been operated. A study in 2012 on 154 sludge emptying businesses in Asia and Africa concluded that FSM services can be a profitable business when operated by entrepreneurs (Chowdhary and Kone, 2012). Sanitation-21, a new approach towards planning for improved sanitation services in low income and middle income countries (Parkinson, 2014). This study aims at depicting the scenario of ongoing fecal sludge management practice in Khulna, Kushtia, and Jhenaidah municipalities. The entire system of fecal sludge management such as latrine user interface, fecal sludge storage/containment, emptying, collection, transportation, treatment, disposal and reuse to be addressed. The laps and gaps will be identified and hence scope of improvement will be recommended.

1.2 Objectives of the study

This study aims at investigating the practice of fecal sludge management and its impact on environment in three municipalities of the south-west coastal region of Bangladesh and therefore proposing strategies for its long-term sustainability. The specific objectives of this study are outlined below:

a) To study the volume of fecal sludge generation and its characteristics in Khulna, Kushtia and Jhenaidah municipalities;
b) To investigate the existing fecal sludge emptying process (both manual and mechanical) in the above three municipalities;
c) To inspect the ongoing treatment and disposal practices and to explore strategies for improvement of fecal sludge management (FSM) in the study area.

1.3 Structure of the dissertation

The study has been offered in six distinct chapters comprising different aspects of this study. The chapters reveal the investigation of various activities, existing practices and scope of services, treatment facilities, sludge characteristics, health and safety issues etc. and comparison of FSM services in three towns and finally proposed a guideline for improvement of fecal sludge management in three cities.

Chapter-1 includes the introduction with background of the study, specifies the objectives of the study, study area with basic information and structure of the dissertation in Bangladesh as the reference for other parts of the world.

Chapter-2 comprises of a comprehensive literature review which states the function of pourashava, describes theoretical background and relevant issues regarding fecal sludge management in these municipalities

Chapter-3 contains elaborate description of the methodology consisting field survey strategy, analytical methods and experimental procedures employed in this study along with the fundamental principles underlying those.

Chapter-4 states the existing scenario of the fecal sludge management practices in the municipalities under this study area. The chapter is arranged with all relevant data and information on FSM based on investigation on the spot and practical work in the field. This chapter is also important because laboratory analysis of collected FS samples from the study areas are reported with graphical presentation.

Chapter-5 states the problems identification and possible solutions for improvement covering toilets, emptying and transportation services, treatment, disposal and reuse, and health and hygiene issues in study area and finally proposals on improvement of fecal sludge management in three cities have been suggested.

Chapter-6 Concludes the findings of the study on FSM with necessary recommendations for the study areas as well as municipalities of Bangladesh.

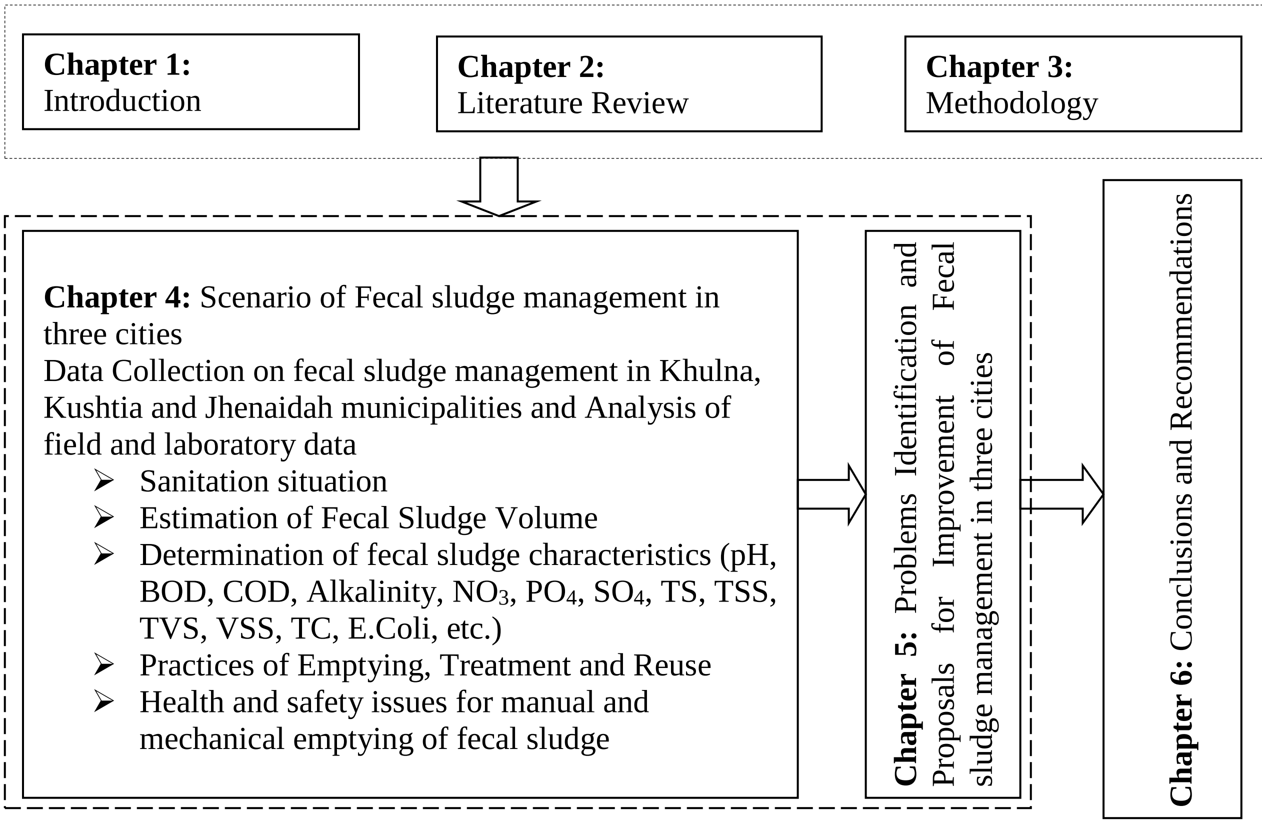


Figure 1.1 Structure of the dissertation

An annotated reference list of the literatures cited in the dissertation follows the last chapter.

Appendix is the complementary part of this report that contains the initial data and numerical information of estimation of sludge generation, test results for sludge characteristics, and information of manual emptiers.

Other Contents are listed in page VI captioned as ‘Table of Content and arranged accordingly in page from I to XIX at the start of this report. The list of references is placed at the end of this report from which necessary and relevant information are quoted for research study.

CHAPTER II

LITERATURE REVIEW

2.1 General

Faecal sludge (FS) comes from onsite sanitation technologies, and has not been transported through a sewer. It is raw or partially digested, a slurry or semisolid, and results from the collection, storage or treatment of combinations of excreta and blackwater, with or without greywater. Solutions for effective and sustainable faecal sludge management (FSM) presents a significant global need. FSM is a relatively new field. However, it is currently rapidly developing and gaining acknowledgement. This chapter reviews the relevant literature with regard to the subject of the dissertation. The global trends in fecal sludge management history and value chain and the practices in Bangladesh were focused. It provides the sanitation situations, conditions of containments, collection and transportation systems, treatment and or reuse. It relates environmental impact also.

2.1.1 What is Fecal Sludge Management?

Feacl Sludge (FS) management deals with on-site sanitation systems, while wastewater management is concerned with sewered sanitation. FS may be treated in separate treatment works or co-treated with sludges produced in wastewater treatment plants. (Strauss *et al.*, 2002). FSM includes the storage, collection, transport, treatment and safe enduse or disposal of FS.

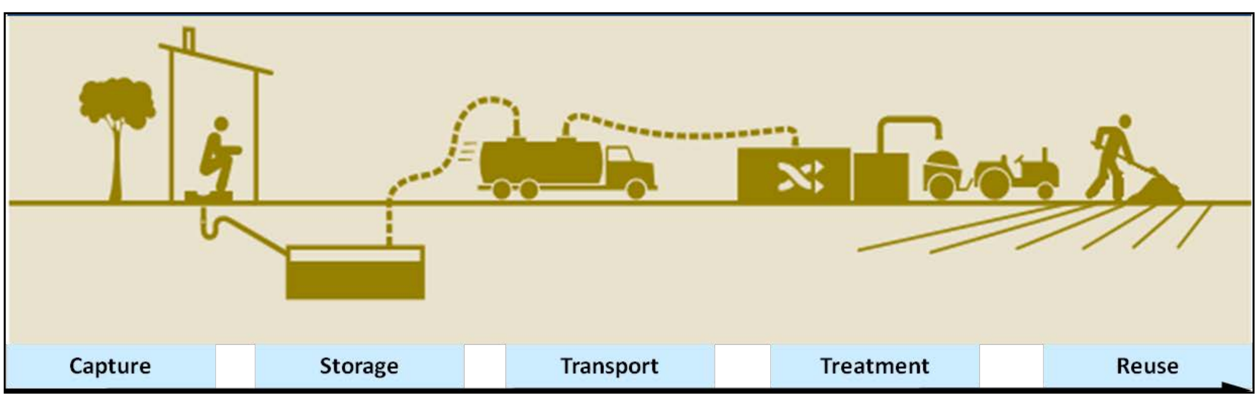


Figure 2.1: FSM Value Chain (EAWAG, 2008)

2.2 Scenario of global Fecal Sludge Management

The sanitation needs of 2.7 billion people worldwide are served by onsite sanitation technologies, and that number is expected to grow to 5 billion by 2030. It is a common perception that onsite technologies fulfil sanitation needs for rural areas, but in reality, around one billion onsite facilities worldwide are in urban areas. FSM is important because although over a billion people in urban and peri-urban areas of Africa, Asia and Latin-America are served by onsite sanitation technologies, faecal sludge is not well managed. In many cities, onsite technologies have much wider coverage than sewer systems. For example, in Sub-Saharan Africa, 65-100% of sanitation access in urban areas is provided through onsite technologies (Strauss *et aI.*, 2000). However, despite the fact that sanitation needs are met through onsite technologies for a vast number of people in urban areas of low- and middle-income countries, there is typically no management system in place for the resulting accumulation of FS. It is evident that the management of FS is a critical need that must be addressed, and that it will continue to play an essential role in the management of global sanitation into the future. In the past, sludge management from onsite facilities has not been a priority of engineers or municipalities, and has traditionally received little to no attention. However, the expansion and development of functioning, conventional sewer networks is not likely to keep pace with the rapid urban expansion typical of low- and middle-income countries. In addition, where sewers and wastewater treatment plants (WWTPs) have been constructed in low-income countries they have most frequently resulted in failures. Over the last 15 years, the thinking of engineers worldwide has started to shift, and people are starting to consider onsite or decentralised technologies as not only long-term viable options, but possibly the more sustainable alternative in many ways compared to sewer-based systems which are prohibitively expensive and resource intensive. In urban areas, it has been demonstrated that, depending on local conditions, the cost of FSM technologies are five times less expensive than conventional sewer-based solutions (Dodane *et al*., 2012).

Increasing access to sanitation is a global priority. Currently one in five children die from diarrheal-related diseases, which is more than that of aids, malaria, and measles combined (UNICEF/WHO, 2009). In addition to health benefits, improved sanitation has significant economic benefits, for example the return on one USD spent on water and sanitation improvements in low-income countries is 5-46 USD depending on the intervention (Hutton *et al*, 2007). Appropriate FSM has significant impacts on human and environmental health. Onsite technologies can represent viable and more affordable options, but only if the entire service chain, including collection, transport, treatment and safe enduse or disposal, is managed adequately. Without an FSM structure in place, when the containment structure fills up, the untreated FS most likely ends up directly in the local environment. For example, in Dakar only 25% of FS that accumulates in onsite facilities is being collected and transported to legitimate FSTPs (BMGF, 2011). When developing sanitation goals and implementing sanitation projects, it is imperative to consider downstream sanitation, beyond only a focus at the household level and only providing toilets. Effective management of FS systems entails transactions and interactions among a variety of people and organisations from the public, private and civil society at every step in the service chain, from the household level user, to collection and transport companies, operators of treatment plants, and the final enduser of treated sludge. Sewer systems and FSM can be complementary, and frequently do exist side-by-side in low-income countries. A very successful example of this management model is in Japan where the systems successfully co-exist in urban areas (Gaulke, 2006).

Figure 2.2: Faecal sludge from a septic tank next to the house in Dakar (photo: Linda Strande)

The complete sanitation service chain is shown in Figure 2.2, the FSM component is specifically the emptying, collection, transport, treatment and enduse or disposal of FS. Factors such as technology designs and options for user interfaces, or onsite collection and storage methods to reduce sludge volumes are covered in more detail in The Compendium of Sanitation Systems and Technologies, which is also available free of charge from the SANDEC website (Tilley *et al.,* 2014). Weak links in the FSM service chain include many factors, such as household level users not being able to afford professional emptying services; collection and transport trucks not being able to access narrow lanes and paths leading to houses; operators not able to afford the transport of FS over large distances to treatment facilities; and the lack of legitimate FS discharge locations or treatment facilities. The solution to overcoming these problems and designing functioning and sustainable FSM requires a systems-level approach that addresses every step in the service chain.

Figure 2.3: Farmer manuring vegetable crops with untreated FS (Photo: McGarry, Taiwan)

A large portion of the thousands tons of sludge generated daily from onsite sanitation systems in the developing countries is not well managed. The fecal sludge (FS) from unsewered family and public toilets and septic tanks are disposed of untreated indiscriminately into lanes, drainage ditches, onto open urban spaces as well as into inland water, estuaries and the sea (Montangero and Strauss, 2004). This improper practices of FS disposal is growing environmental and sanitary concern since many water-borne diseases are transmitted from feces to humans through water and soil pollution (Kengne *et al*. 2011).

The Comprehensive Environmental Response, Compensation, and Liability Act (CERLA) of 1980, better known as "Superfund" became law to provide for liability, compensation, cleanup and emergency response for hazardous substances released into the environment and the cleanup of inactive hazardous waste disposal sites. CERLA was generally intended to give EPA authority and funds to clean up abandoned waste sites and to respond to emergencies related to hazardous waste. The law provides for both response and enforcement mechanisms. (Davis *et al.*, 1998).

Compared to wastewater management, the development of strategies and treatment options adapted to conditions prevailing in developing countries have long been neglected as regards faecal sludges (FS) – the by-products of on-site sanitation installations. In recent years, an encouraging number of initiatives towards improved FS management, including appropriate FS treatment schemes, have been developed , particularly so in several West African countries (Senegal, Mali, Ivory Coast, Burkina Faso, Ghana), in South East Asia (Nepal, Thailand, Vi-etnam) and in Latin America. These initiatives assist urban dwellers and authorities to overcome the challenges of indiscriminate and uncontrolled disposal of faecal sludge into drains, canals and onto open spaces, thus creating a "faecal film" in urban areas that impair public health and cause pollution. (Strauss *et al.*, 2002).

2.2.1 Millennium Development Goal (MDG)

Progress towards the Millennium Development Goals (MDGs) has been successful in increasing access to improved sanitation facilities. However, providing adequate access to sanitation facilities does not end when onsite technologies are built. The promotion of onsite technologies has greatly reduced open defecation, but without solutions. Target 7C - reducing by half the number of people without access to 'improved' sanitation. Improved is defined as systems that hygienically separate human excreta from human contact, and includes: flush toilets, connection to a piped sewer system, connection to a septic system, flush/pour-flush to a pit latrine, ventilated improved pit (VIP) latrines, and composting toilets.

According to Joint Monitoring Program (WHO/UNICEF, 2015), the progress on Millennium Development Goal (MDG) as follows:

- The world has missed the MDG target for sanitation by almost 700 million people.
- 95 countries have met the MDG sanitation target.
- 68 per cent of the global population now uses an improved sanitation facility.
- 2.1 billion People have gained access to an improved sanitation facility since 1990.
- In 2015, 47 countries have less than 50% coverage of improved sanitation.
- Half the rural population uses improved sanitation facilities compared with four out five people in urban areas.
- One in three (2.4 billion) people still lack improved sanitation facilities and one in eight people (946 million) practise open defecation.

2.2.2 The Sustainable Development Goals (SDG)

After attaining MDGs, the world's eye is on Sustainable Development Goals. In SDGs, there are some goals on sanitation as

- Goal 6: Ensure availability and sustainable management of water and sanitation for all
- Target 6.2 by 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.
- Target 6.3 by 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

2.3 FSM in South Asia:

In Asian countries Thailand, Vietnam, Indonesia, Philippines, Malaysia are much advanced in fecal sludge management. Besides this, some countries of South Asia like India, Sri Lanka, Nepal has just started to work on the issues of Fecal Sludge Management.

FSM in Sri Lanka:

At present, septage is one of the most neglected urban waste streams in Sri Lanka. By considering an increase in access to septic truck services and growing private sector participation, septage management needs attention. If left unmanaged, septage can create an adverse impact on the environment and the health of the people.

Responsibility of septage management has dropped to a great extent in all three tiers of the governance level. At the local level is clearly assigned to the LAs. At the provincial level, the responsibilities are with the PCs, but they do not play an active role in managing septage. The national responsibility with regards to septage management is scattered among many different ministries. As the capacities are limited at the provincial level, the practical way forward would be to allow national-level regulations to spill over to the local level.

Environmental pollution and associated health risks associated with present dumping practices, call for an integrated approach to prevent pollution and highlights the vital need for effective interventions.

Figure 2.4: *Septage disposal. Sri Lanka/Nuwara Eliya sanitation project, 2008, Photo: Flickr/USAID*

An international research institute is helping the government of Sri Lanka to improve septage management in the country. IWMI will contribute research data for the drafting of a septage management component of the national sanitation policy. Only about 3% of Sri Lankans have a sewerage connection while the rest rely on latrines and septic tanks for sanitation. Safe disposal of septage (fecal sludge) is a problem because of a lack of treatment facilities in large parts of the country. IWMI is studying a new approach in cities around the world, which treats the sludge so that it can be safely reused as agricultural fertilizer. With the rising costs of imported fertiliser, such an approach would not only benefit farmers but also allow better sanitation and environmental protection for all (FSM in Sri Lanka, 2016).

FSM in India:

Sanitation overall is generally considered one of India's biggest challenges and is often the first thing that visitors to the country notice upon arrival. Development agencies and funders are encouraging creation of innovative technologies and programs to solve the country's sanitation issues. Prime Minister Modi is pushing this work through the "My Clean India" campaign, garnering private investment and partnerships with USAID. With this support, India is poised to introduce major changes that can improve the sanitation and health of its people, which at their current state are massive and overwhelming. To back up, fecal sludge management refers to the removal, treatment, and disposal of fecal sludge from holding tanks (septic or networked through sewerage pipes). Fecal sludge is different from overall sewerage in that it contains mostly human bodily waste rather than the waste that drains from kitchens, etc.

Given these issues of collection, treatment, and disposal, it is exciting that innovators are starting to look to this waste as a resource rather than burden. While there is value of innovation at each level of the sanitation chain, mostly due to the human resource and health potential in infrastructure building and collecting waste, there is additional value add in turning the fecal sludge matter into an environmentally beneficial and profitable resource. (FSM in India, 2016)

FSM in Nepal:

In the last few years, access to basic sanitation has increased to 70% (National Management Information Project, NMIP, 2014) in Nepal. Nepal is the most rapidly urbanizing country in

South Asia - the urban population is estimated to have increased to 38.5% now from 17% in 2011. Urbanisation as well as concerted efforts by the government and development agencies to improve the sanitation and hygiene situation has resulted in several districts, villages and municipalities being declared open-defecation free (ODF). As per census 2011, 30% of urban population has toilets connected to sewer system while 48% have septic tanks. There is an urgent need to develop strategies and action plans to address the resulting faecal sludge problem. Effective town-wide Faecal sludge Management (FSM) services are essential for a healthy and sustainable future for all small towns, where most of the population uses on-site sanitation. CDD Society with support from BORDA, is supporting the DWSS under the Third Small Towns Water Supply and Sanitation Project, co-financed by the ADB. (Faecal Sludge Management in Nepal – CDD and BORDA extend support)

Figure 2.5: A failed Fecal Sludge Management facility in Nepal. Photo credit: ENPHO

2.4 Fecal Sludge Management in Bangladesh perspective

Bangladesh has remarkable improvement in coverage of sanitation. According to JMP, in 2015 Bangladesh has made good progress towards MDG target. Open defecation has been reduced to only 1%, a milestone change from 42% in 2003. Improved sanitation coverage is 61%, an increase of 28% since 2003. Still 28% people are sharing latrines and 10% people are using unimproved latrines. (Joint Monitoring Program of WHO/UNICEF, 2015). The dissemination of long-tested sanitation promotion techniques including community-led total sanitation (CLTS) with the followings dynamics contributed to achieve the results:

- Strong role of LGIs (Union Parishads, Pourashavas/Municipalities)
- Government-NGO collaboration at national, district, and sub-district levels
- Long-term assistance from donors/development partners
- Media campaigns
- Technological innovations and creative marketing approaches
- Easy access to latrine materials and skill masons in a local market.

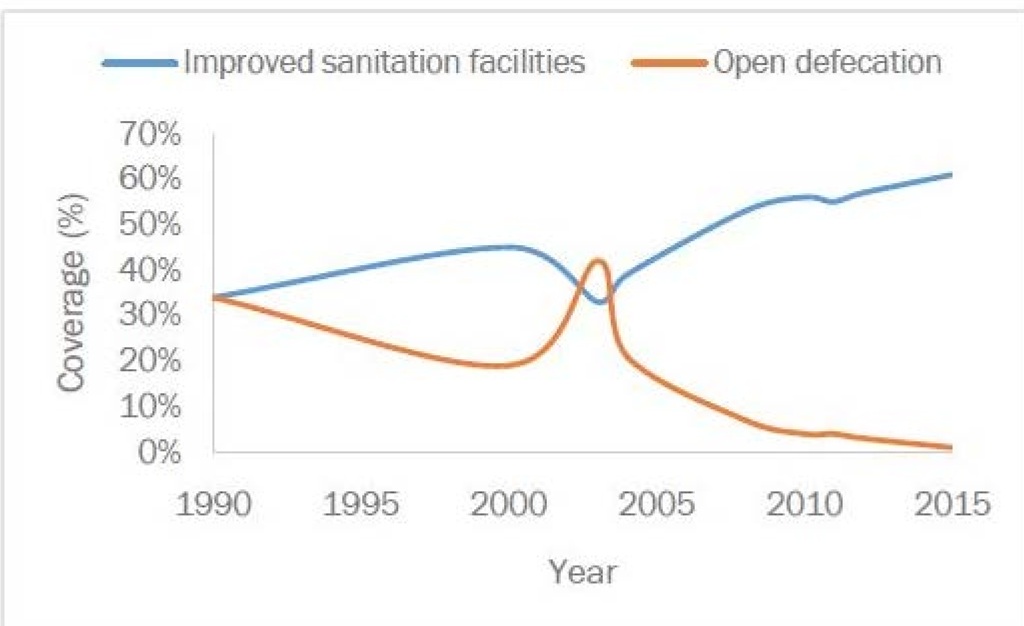


Figure 2.6: Bangladesh Sanitation Coverage since 1990

2.4.1 Actors of relevant departments/stakeholders

There are many actors playing roles in Fecal Sludge Management. These are central government, local government, different departments or agencies of government and CBOs or NGOs.

2.4.2 National Policies of Bangladesh

The political commitment of the Government of Bangladesh (GoB) to sanitation has been the major driving force for the sanitation movement in the country. The major policies and strategies guiding the sanitation movement in Bangladesh (SACOSAN-VI Paper 2016) are:

- National Water Management Plan, 2004
- The National Sanitation Strategy, 2005
- The Pro-Poor Strategy for Water and Sanitation, 2005
- The Sector Development Plan, 2011-25
- The National Strategy for Water and Sanitation in Hard to Reach Areas of Bangladesh, 2012
- The National Hygiene Promotion Strategy for Water Supply and Sanitation Sector in Bangladesh, 2012
- The National Cost Sharing Strategy for Water Supply and Sanitation Sector in Bangladesh, 2012
- Bangladesh National Hygiene Baseline Survey 2014
- National Strategy for Water Supply and Sanitation, 2014

    - Establish fecal sludge management (Strategy 5)
    - Institutional and Regulatory Framework (IRF) for Fecal Sludge Management (FSM) in Bangladesh (draft), 2015 [Recognizing that no specific institutional and regulatory framework exist for fecal sludge management, the LGD initiated the process of development of institutional and regulatory framework for Fecal Sludge Management (FSM) in 2014. The framework will guide the activities related to FSM throughout the country.

2.4.3 Bangladesh National Building Code 2011 8-271:

In Chapter-6 of BNBC 2011 the following subject matters related to FSM are mentioned below.

License Requirement (BNBC 6.5.1): No individual, partnership, corporation or firm shall engage in the business of installation, repair, alteration or maintenance of plumbing, drainage and sanitation work without obtaining a license from the Authority.

Examination and Certification (BNBC 6.5.2): The Building Authority shall establish a plumber's examination board. The board will determine the requirements for the qualification and procedures for examination of applicants for license. The Authority will issue license to such applicants who meet the qualifications therefore and successfully pass the examination conducted by the board.

Septic Tank (BNBC 6.9.12.1): Septic tank(s) discharging into either a subsurface disposal field or one or more seepage pits shall be required for the approval of drainage and sanitation plans for the places where public sewers are not available.

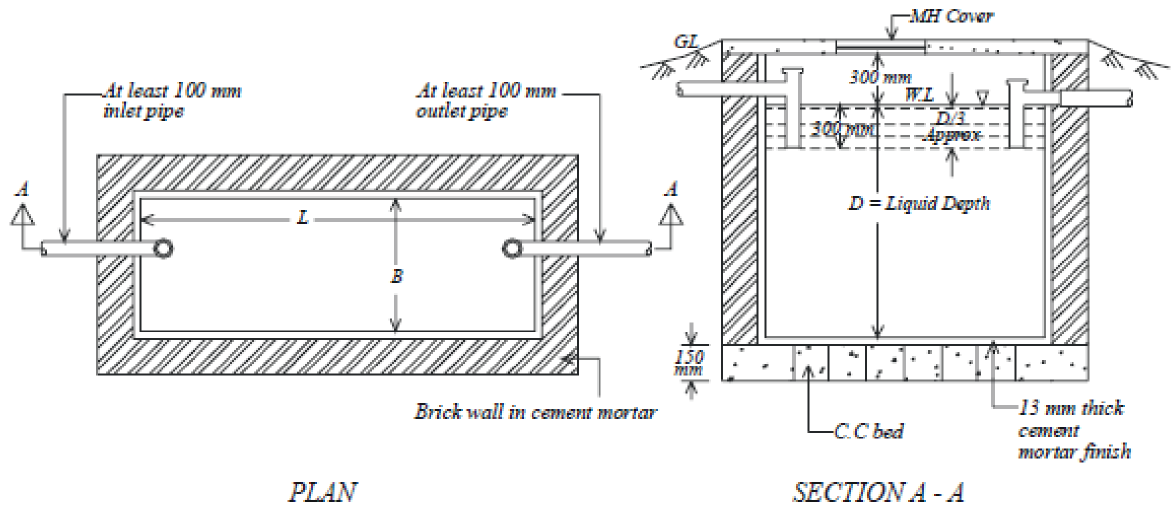


FIG. 2.7: Typical one chamber brick septic tank

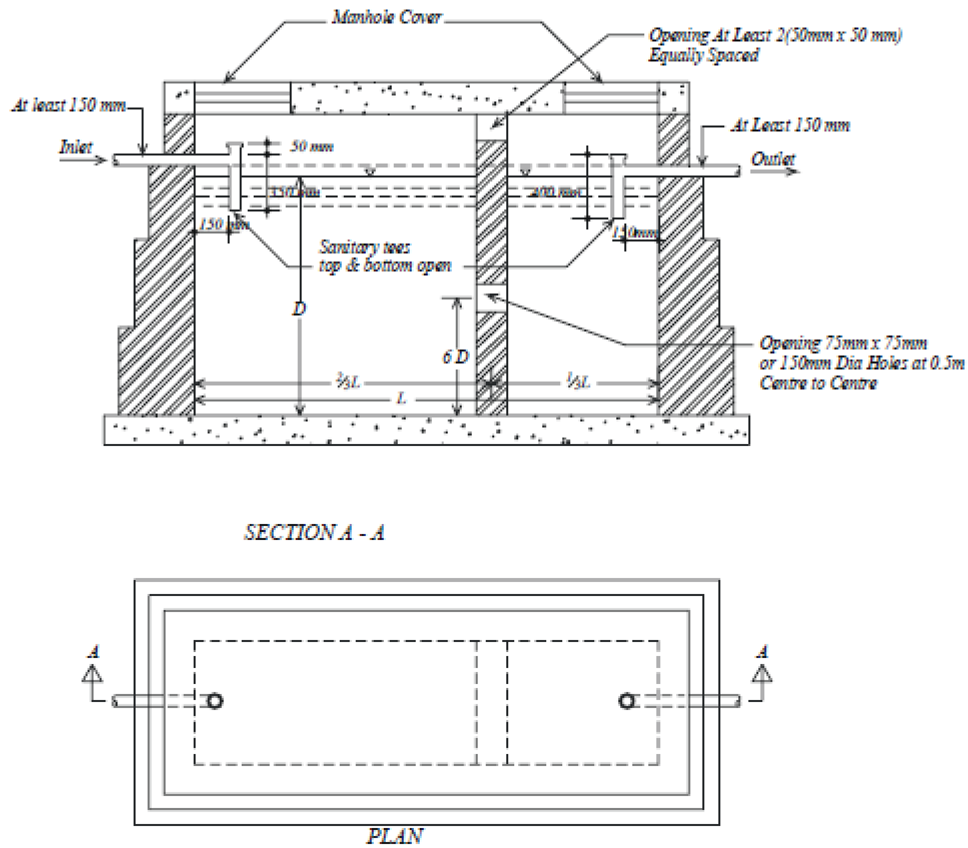


Figure 2.8: Typical two chamber concrete septic tank

Sullage water shall not be discharged into the septic tank (BNBC 6.9.12.4). Effluent from septic tank(s) shall not discharge into open water courses. (BNBC 6.9.12.5). The septic tank shall have a minimum liquid capacity of 2000 liters, minimum width 1 m and minimum liquid depth 1 m. The minimum length of a septic tank shall be at least thrice its width. It is recommended that the maximum length of a septic tank shall be not more than 4 times its width. (BNBC 6.9.12.8). The maximum size of a septic tank shall be limited to the number of users not exceeding 300 persons for residential buildings. (BNBC 6.9.12.9). The volume required for digested sludge and scum may be computed on the basis of 0.04 m3/capita/year. There shall be a clearance between top of the liquid level and bottom of the tank cover slab which shall be at least 300 mm. (BNBC 6.9.12.10). The liquid retention time of a septic tank shall be at least 1 day. (BNBC 6.9.12.11). The desludging frequency of a septic tank shall be at least 6 months interval and maximum once a year. (BNBC 6.9.12.12). It is recommended to use two chamber septic tank when the capacity of a septic tank exceeds 3000 liters. The inlet compartment of a two chamber septic tank shall have a capacity not less than two-third of its total capacity (BNBC 6.9.12.13). Imhoff tanks shall be used where more than 300 peoples of residential buildings are to be served. (BNBC 6.9.13.2). The digestion chamber should have a capacity to store about 6 to 12 months digested sludge.

Seepage pit (soak pit) (BNBC 6.9.15.7) shall be lined with stone, brick or concrete blocks laid up dry with open joints that are backed up with at least 75 mm coarse aggregate. A reinforced concrete cover shall be provided. For cover area more than 0.75 m2 the pit shall have an access manhole. The bottom of the pit shall be filled with coarse gravel, or crushed stone/brick to a depth of 0.3 m.

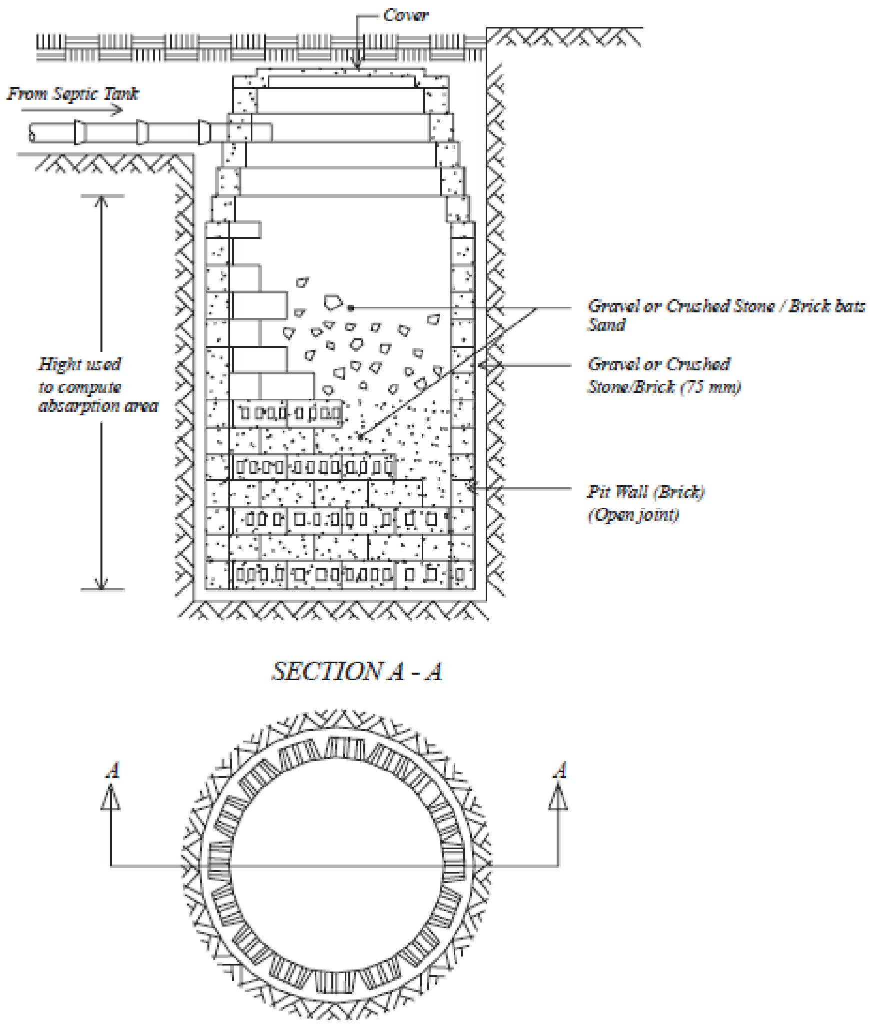


Figure 2.9: Details of a seepage pit.

2.4.4 Functions of Pourashavsa/Municipalities

According to local government (municipality) ordinance, 2009

1) **Responsibility and Function of Municipality**:

(a) To provide all types of citizen benefit to citizens of respective area according to established rules under this and other ordinance.

(b) To make articulation between municipal administration and government employees and to take articulated programs.

(c) Infrastructural development, implementation and issuing urban development plan including building control to provide municipal service to the citizen of municipal area.

(d) Maintain security and discipline of citizen.

2) To fulfill aims of sub-section (1), municipality's responsibilities shall be –

(a) Water supply for residential, industrial and commercial use.

(b) Water and sanitation.

(c) Waste management.

(d) Issuing plan to ensure economic and social justice.

(e) Construction of road, footpath to develop communication system and construct terminal for the benefit of people's movement and goods.

(f) Activities under birth and death registration act 2004 (29 no, act of 2004).

(g) Traffic management planning for better transport management, passenger shade, road light parking place, bus stand and bus stop for walkers.

(h) Public health and environment conservation, tree plantation and conservation.

(I) Market and slaughter house setup and management.

(j) Create and spread the opportunity and support to sports, games, disport, amusement and increase beautification of the locality. And

(k) Any other functions under ordinance, rules, regulatory or any order from government.

(3) Functions, described above cannot adjourn for the benefit of citizen, if the municipality have not own technical management and financial capacity to perform any functions.

(4) Government shall provide necessary order if any function according to sub-section 1 and 2 is not executed.

(5) Beside these functions, municipality shall perform functions described in second schedule according to its fund.

2.4.5 FSM in Pourashava/Municipalities

Sanitation refers to all conditions that affect health. Pourashavas are responsible for improvement of health conditions in Pourashava area. Sanitation is necessary to overcome the effects of human activities on his environment. The increase in population and the movement of population into urban areas, i.e. Pourashava and City Corporation have intensive environmental-control difficulties in those areas. Some of the pourashavas have mechanical emptying services but without treatment plant or even any designated site for disposal. So, they are collecting from pit or septic tank but dispose here and there which is more dangerous than keeping in containment.

2.4.6 Social and Technological Advancements

The tremendous achievement that Bangladesh has made in reducing open defecation to a single digit (from 34% in 1990 to 1% in 2015) in just 25 years could be attributed to the early recognition that attitudes and behaviors are as important as any technology or infrastructure. Bangladesh approached the sanitation problem recognizing that social and cultural norms are central to changing the practice. A national sanitation campaign started by the GoB in 2003, targeting the MDG goal on improved sanitation, brought together NGOs, international agencies, and other stakeholders. The factors that led to sanitation success in Bangladesh include an emphasis on stopping open defecation, investment in hygiene promotion and social intermediation and provision of affordable sanitation options to the poor (the Water and Sanitation Program (WSP), 2005). The challenge of fecal sludge management in most developing countries is acute. Bangladesh is one of the developing countries in the world.

2.5 Quantification of faecal sludge

Deriving accurate estimates for the volume of FS produced is essential for the proper sizing of infrastructure required for collection and transport networks, discharge sites, treatment plants, and enduse or disposal options. Due to the variability of FS volumes generated it is important to make estimates based on the requirements specifically for each location and not to estimate values based on literature. However, no proven methods exist for quantifying the production of FS in urban areas, and the data collection required in order to accurately quantify FS volumes would be too labour intensive, especially in areas where there is no existing information. There is therefore a need to develop methodologies for providing reasonable estimates. (Charles *et al.* 2015)

2.6 Characterizations of faecal sludge

Parameters that should be considered for the characterisation of FS include solids concentration, chemical oxygen demand (COD), biochemical oxygen demand (BOD), nutrients, pathogens, and metals. These parameters are the same as those considered for domestic wastewater analysis, however, it needs to be emphasised that the characteristics of domestic wastewater and FS are very different. The organic matter, total solids, ammonium, and helminth egg concentrations in FS are typically higher by a factor of ten or a hundred compared to wastewater sludge (Montangero and Strauss, 2002). Analysis standards are still in development. Still, as this is a field of high research interest, there are many interesting innovations and research results to be reported and expected.

2.7 Sludge collection method

Pit emptying constitutes a major problem in many places, both technically and managerially. In many countries and cities, both mechanised and manual pit emptying services are being offered. Mechanised services are rendered by municipal authorities or by small to medium-sized enterprises

2.7.1 Manual emptying

.Manual emptying can mean one of two things: The waste/sludge is emptied by hand using buckets and shovels or by a portable, manually operated pump system (e. g. “MAPET: Manual Pit Emptying Technology”).

If a container (pit, tank etc.) pit is emptied by hand, every precaution should be taken to prevent anyone from accessing the pit. If, for whatever reason the pit has to be entered, the emptier has to be fitted with adequate protection and safely secured by a rope to the surface in the event he has to be pulled out quickly. Appropriate equipment (e. g. long-handle shovels) should be provided to avoid accessing the pit. A MAPET system, comprises a hand-pump connected to a vacuum tank mounted on a pushcart. A hose connected to the tank is used to suck sludge from a pit. When the hand-pump is turned, air is sucked out of the vacuum tank, which in turn sucks up the sludge into the tank. Depending on sludge consistency, MAPET can pump the sludge from a maximum depth of 3 m.

2.7.2 Mechanical emptying

Most pits/septic tanks, however, are emptied by vacuum trucks or tankers equipped with a pump and a storage tank. The pump is connected to a hose, which is lowered down into a septic tank or pit, and the sludge is pumped up into the tank. Generally, the storage capacity of a vacuum tanker ranges between 4 and 6 m3. Depending on the system, the material to be pumped out can sometimes become so compacted that it cannot easily be removed. In these situations, the solids have to be liquefied with water in order to flow more easily. If water is not available, the waste will have to be removed manually. FS collection and haulage are particularly challenging in metropolitan centres with their often large and very densely built-up, low-income districts. Large trucks often have difficulty accessing pits/septic tanks in areas with narrow or inaccessible roads/lanes.

Vacutug: The Sewer and Drainage Company of Haiphong (N. Vietnam), a public utility enterprise, is responsible for septage collection. Collection is carried out by vacuum tankers and small vacuum tugs for areas of difficult access and used with intermediate-storage-tanks mounted on a hook-lift truck. The mini-vacuum-tugs, developed by the Haiphong drainage company in collaboration with a local manufacturer, have a capacity of 350 L and cost around USD 4,000. The combination of large and small equipment has proven successful, and almost 100 % of the houses can be serviced. Mini-tugs used together with an intermediate storage tank that can be hook-lifted and hauled away. (Strauss *et al*., 2002)

2.8 Major technologies for solid-liquid separation and FS treatment

Separation of the FS solids from the liquids is the process-of-choice in FS treatment, unless FS is co-treated in an existing or planned wastewater treatment plant, and if the FS loads are small compared to the flow of wastewater. Solid-liquid separation may be achieved through sedimentation and thickening in ponds or tanks or through filtration and drying in sludge drying beds. The resulting solid and liquid fractions both require further treatment. Though the technologies used for solid-liquid separation, secondary treatment and co-treatment with wastewater are often the same, their design and mode of operation vary. A few technology options for the solid-liquid separation and further treatment are illustrated in Figure 2.11.

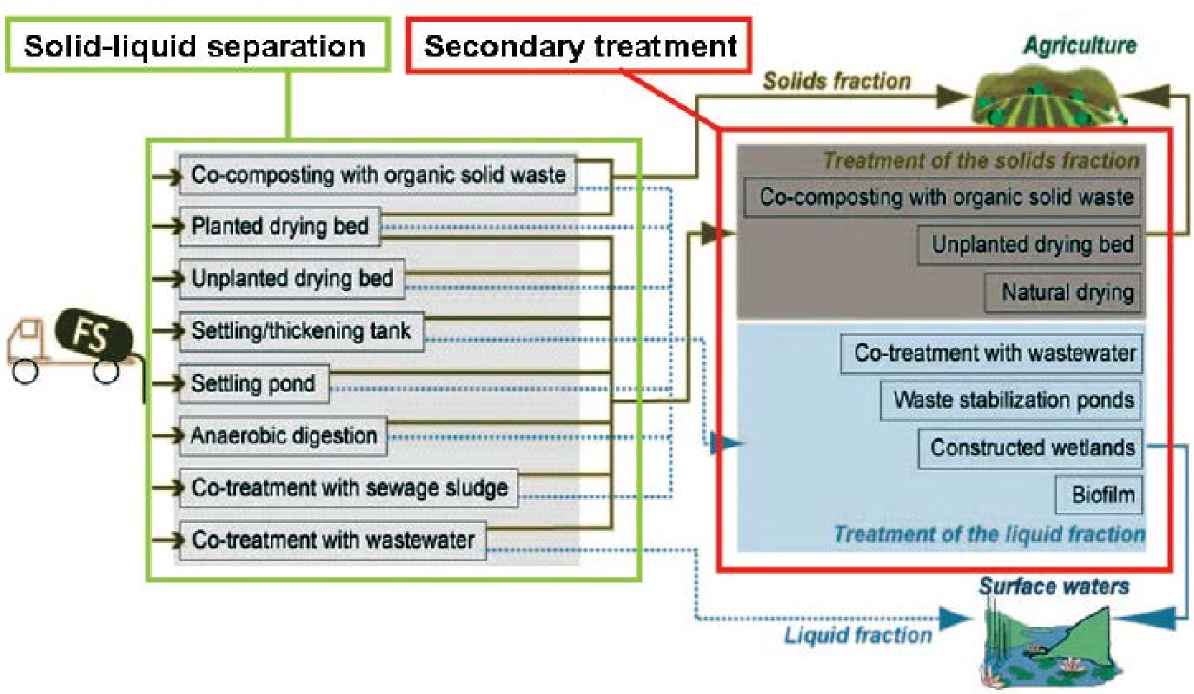


Figure 2.10: Overview of potential, modest-cost options for fecal sludge treatment. The schematic drawing illustrates how after separation, the solid and liquid fractions of FS can be further processed or used. (Strauss *et at.*, 2002)

2.8.1 Drying bed

The drying bed consists of a gravel-sand filter and a drainage system. A drying bed separates solids from liquids by the physical filtration process to drainage and evaporation. The separated solid is deposited in the bed. Drying beds are often used with and without sand/gravel media. Sludge obtained from drying beds is not free of pathogens especially helminthes eggs. However, it can be used either as a soil conditioner or fertilizer in agriculture under proper design and operation. This system can also be used as second stage of dewatering from anaerobic digestion tank.

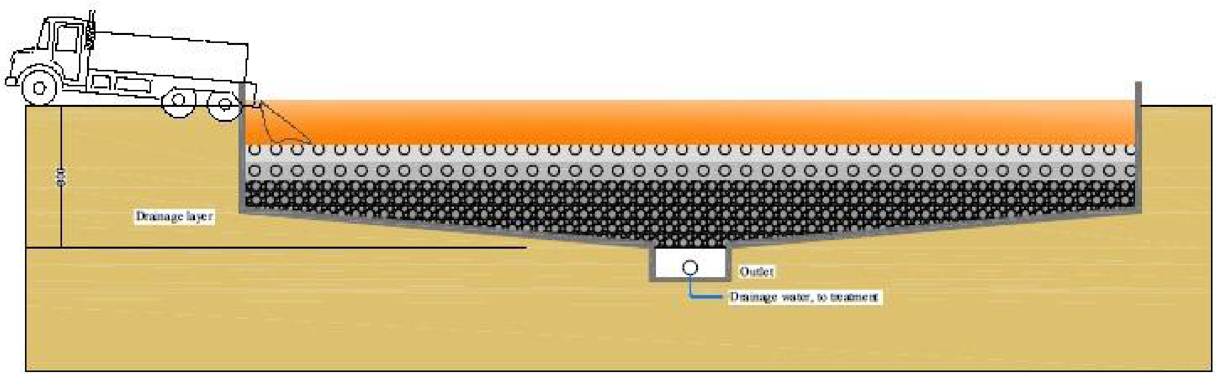


Figure 2.11 Drying bed system

Advantage of system

- Low moisture content in dried sludge can be obtained
- Technology is reliable and easy for operation

Disadvantage of system

- Dried sludge still has pathogens, treatment before reuse is recommended
- Not suitable for fresh sludge unless it is not diluted sludge
- Need time for drying, in case of raining season, the cover is needed
- Harvesting sludge is needed after dried otherwise the bed will be clogged in the next run

2.8.2 Constructed wetland

Constructed wetlands (CWs) are a natural, low-cost, eco-technological biological wastewater treatment technology, which are designed to replicate the processes found in natural wetland ecosystems. The shape of constructed wetlands may vary based on design. However, it is a shallow basin filled with some sort of filter material known as media, sand or gravel.

A constructed wetland typically comprises following components: a basin, media, vegetation, liner and inlet/outlet arrangement system. During treatment, the wastewater/fecal sludge are fed into the basin filled with media and planted with vegetation. The wastewater/fecal sludge flow over or through the substrate depending upon the type of constructed wetlands. The mechanisms of treatment are subjected to physical, chemical, as well as microbial interactions, where it will be treated.

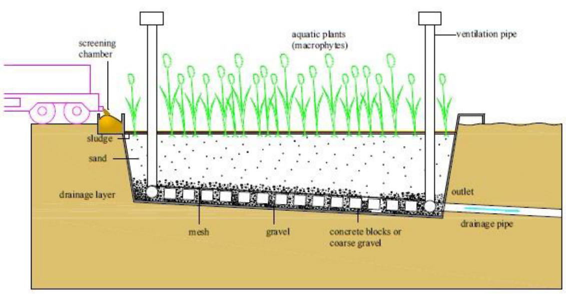


Figure 2.12 Free-Water Surface Constructed Wetland

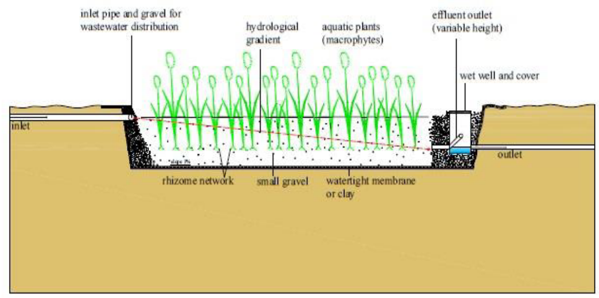


Figure 2.13 Horizontal Subsurface Flow Constructed Wetland

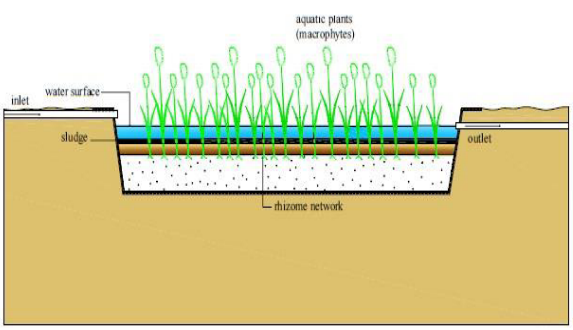


Figure 2.14a: Vertical flow Constructed Wetland

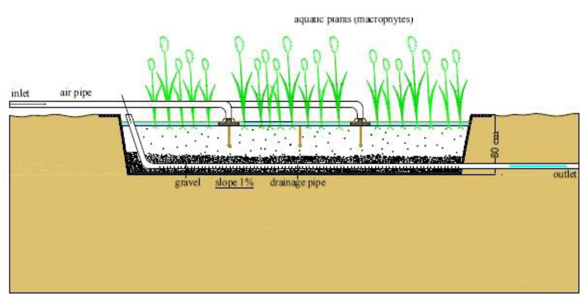


Figure 2.14b: Vertical flow Constructed Wetland

At the early stages of operation, attention is required mainly on the growth of planted vegetation on constructed wetland. The contamination level and organic load will be much higher in fecal sludge and needs to be acclimatized slowly. Therefore, a proper and complete process needs to be carefully followed during the startup of constructed wetlands for fecal sludge treatment (Ecological treatment system, AIT).The optimum loading rate is considered as 250 kg total solids (TS) per m^2/year or 8 m^3/week, and resulting sludge accumulation is about 10-20 cm per year (AIT, 2001). The series of constructed wetland as vertical flow and horizontal subsurface types are normally applied for treating FS.

Advantage of system

- Complete system
- The process of dewatering and stabilization will be achieved
- It is free of pathogen in sludge especially helminth eggs because it is retained for more than 5 years
- Operation can continuously run without sludge harvesting

Disadvantage of system

- Need time for plant growth
- Small plant may not stand for the high loadings
- Plant harvesting is needed when it is wilting or old

2.8.3 Sedimentation / Stabilization Pond

Ponds are larger and the sediment removal interval is longer. The pond can be anaerobic depending upon the organic load in effluents. Remained part of the sludge in the effluents will be accumulated on its bottom which needs to be removed periodically. Pond is suitable for sufficient land. This system can be used for fresh sludge treatment.

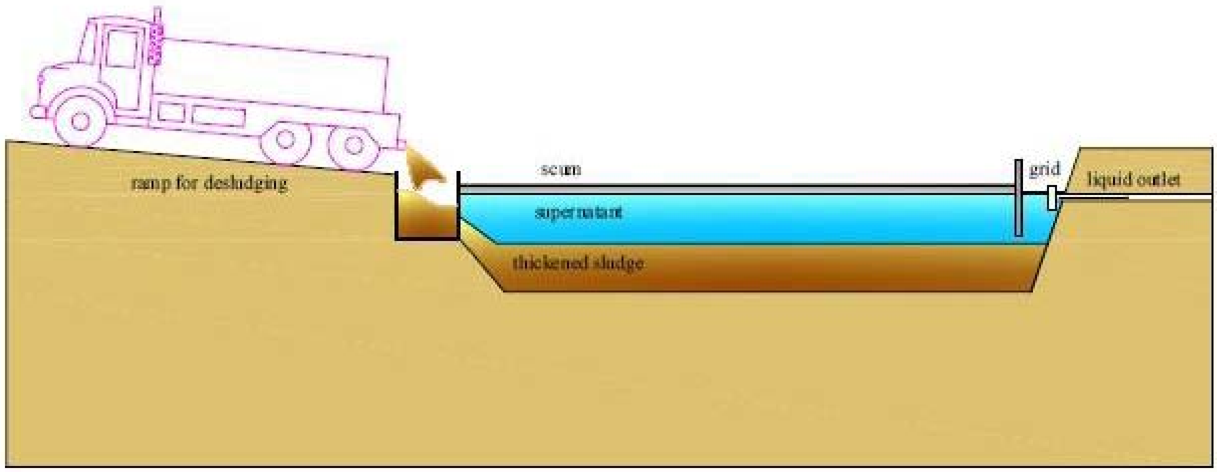


Figure 2.15: Sedimentation pond

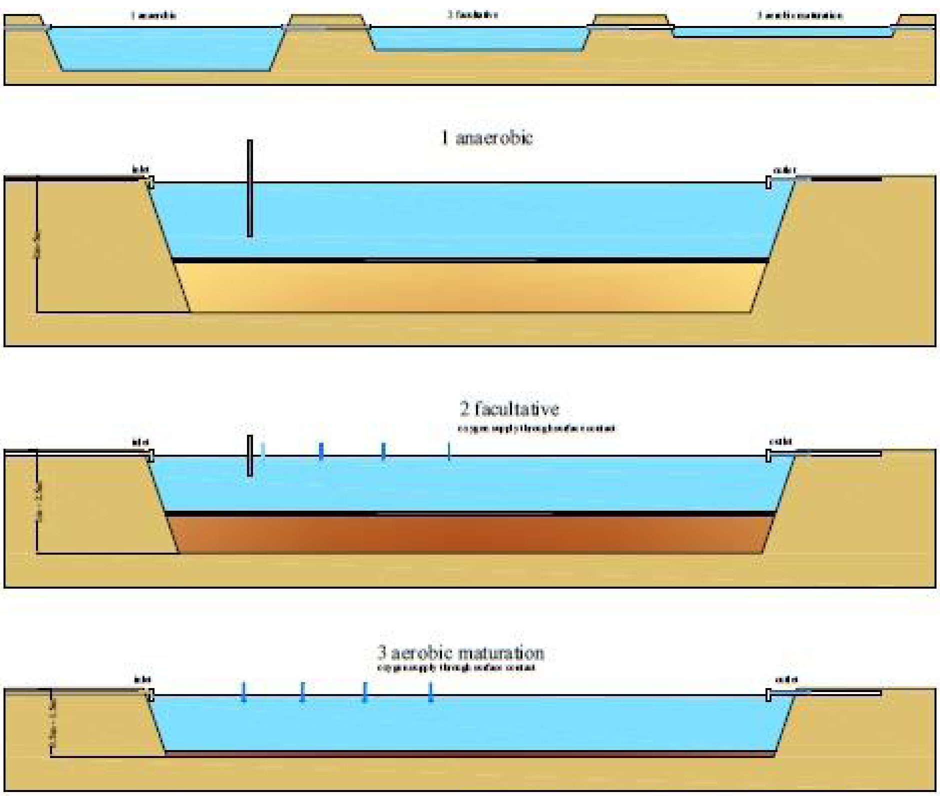


Figure 2.16: Stabilization pond

Advantage of system

- Simple in operation
- Low- cost of construction
- Sedimentation and stabilization capacity is better than the settling tanks

Disadvantage of system

- Require large area
- Release of NH3/NH4 in presence of fresh FS may hinder well function of pond

2.8.4 Thickening Tank

Settling-thickening tanks are used to achieve separation of the liquid and solid fractions of faecal sludge (FS). They were first developed for primary wastewater treatment, and for clarification following secondary wastewater treatment, and it is the same mechanism for solids-liquid separation as that employed in septic tanks. Settling-thickening tanks for FS treatment are rectangular tanks, where FS is discharged into an inlet at the top of one side and the supernatant exits through an outlet situated at the opposite side, while settled solids are retained at the bottom of the tank, and scum floats on the surface. During the retention time, the heavier particles settle out and thicken at the bottom of the tank as a result of gravitational forces. Lighter particles, such as fats, oils and grease, float to the top of the tank. As solids are collected at the bottom of the tank, the liquid supernatant is discharged through the outlet.

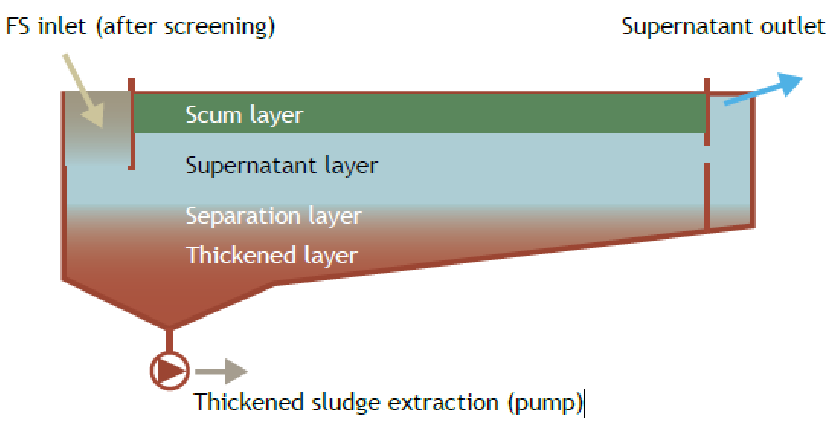


Figure 2.17: Schematic of the zones in a settling-thickening tank.

Advantages:

- Thickened sludge is easier to handle and less prone to splashing and spraying
- Can be built and repaired with locally available Materials
- Relatively low capital costs; low operating costs
- No electrical energy is required

Disadvantages:

- Requires a large land area
- Odours and flies are normally noticeable
- Long storage times
- Requires front-end loader for desludging
- Requires expert design and construction
- Effluent and sludge require further treatment

2.8.5 Anaerobic digestion and biogas production

Fresh sludge that contains biodegradable organic matter is digested anaerobically either alone or mixed with animal dung or vegetable waste. Methane gas (CH4) will be produced from the process. Anaerobic digestion system for treating fresh FS has a potential to get biogas.

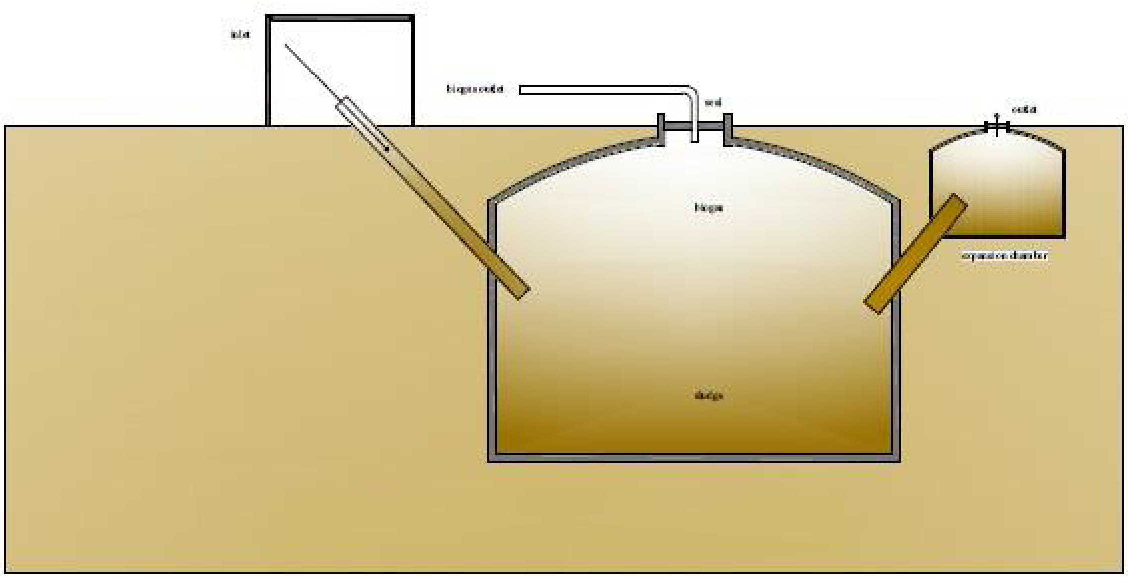


Figure 2.18 Anaerobic Biogas Reactor

Advantage of system

- Biogas is the byproduct
- Fresh sludge can be stabilized

Disadvantage of system

- Higher cost of installation
- Additional treatment is required
- Difficulties in removing settled and thickened solid in tank

2.9 Enduse of Treatment Products

There are a wide range of FS treatment technologies that can be combined in many different ways. All treatment processes result in end products which are either treated further, disposed of, or harnessed in some way for resource recovery. The potential use of end products should be considered from the initial design phase of any complete FS management (FSM) system, as the treatment technologies used are intrinsically linked to the quality of end products generated. A summary of resource recovery options covered in this chapter is provided in Table 2.1.

Table 2.1 Summary of potential resource recovery options from faecal sludge

Produced Product	**Treatment or Processing Technology**
Soil conditioner	Untreated FS, Sludge from drying beds, Compost, Pelletising process, Digestate from anaerobic digestion, Residual from Black Soldier fly
Reclaimed water	Untreated liquid FS, Treatment plant effluent
Protein	Black Soldier fly process
Fish and plants	Stabilisation ponds or effluent for aquaculture
Fodder and plants	Planted drying beds
Building materials	Incorporation of dried sludge
Biofuels	Biogas from anaerobic digestion, Incineration/co-combustion of dried sludge, Pyrolysis of FS, Biodiesel from FS

2.10 Shit Flow Diagrams (SFDs):

A shit flow diagram (SFD) is an excel---based tool that allows to clearly and simply summarize what happens to excreta in a city along the pathways from defecation to disposal or end---use. The tool hereby intends to present the safe and unsafe management of excreta in an easy flowchart graphic regarding population coverage.

SFDs are developed as part of a joint initiative by renowned practitioners and researchers active in the FSM sector and managed under the Sustainable Sanitation Alliance, intending to promote a better understanding of excreta management in the context or urban sanitation.

SFDs are designed:

- as advocacy and decision---support tools
- to be easily understood by non---technical key stakeholders and the civil society
- for overseeing and monitoring the development of city---wide sanitation level

Specific Applications

- Prevailing pathways are presented in a standardised way along the entire FSM service chain
- Red arrows indicate unsafely managed flows which are lost to the environment
- Green arrows indicate safely managed and captured flows
- The width of the flowchart arrows is representative for the coverage rates
- The resulting percentages at the tip of the arrows allow to conclude on population coverage of safe or unsafe management

CHAPTER III

METHODOLOGY

3.1 General:

In this chapter, the overall methodology to conduct the research study has been described covering the location and basic information of the study area with the municipality base maps. The methodology also includes review of literature, extensive data collection, FS sample collection and examination in laboratory, data analysis and presentatrion, questionnaire survey and peoples perception.

3.2 Study area

The research study was conducted in one City Corporation and two municipalities under Khulna division of southern region of Bangladesh. The urban cities and towns in Khulna Division include one City Corporation (Khulna City Corporation), nine district level municipality towns (Bagerhat, Chuadanga, Jessore, Jhenaidah, Kushtia, Magura, Meherpur, Narail and Satkhira) and 58 upazila level municipalities/towns (36 municipalities, 22 towns). The study was done in 1. Khulna City Corporation, 2. Kushtia Municipality and 3. Jhenaidah Municipality.

Khulna City Corporation

Khulna is the third largest industrial city of Bangladesh. It is a divisional city and regional hub of administrative, institutional, commercial and academic affairs. Khulna city is located on the banks of the Rupsha and Bhairab Rivers (another river, the Mayur, is almost dead due to siltation and waste disposal). Khulna is 4 m above mean sea level (MSL) and its area is 45.65 square km.

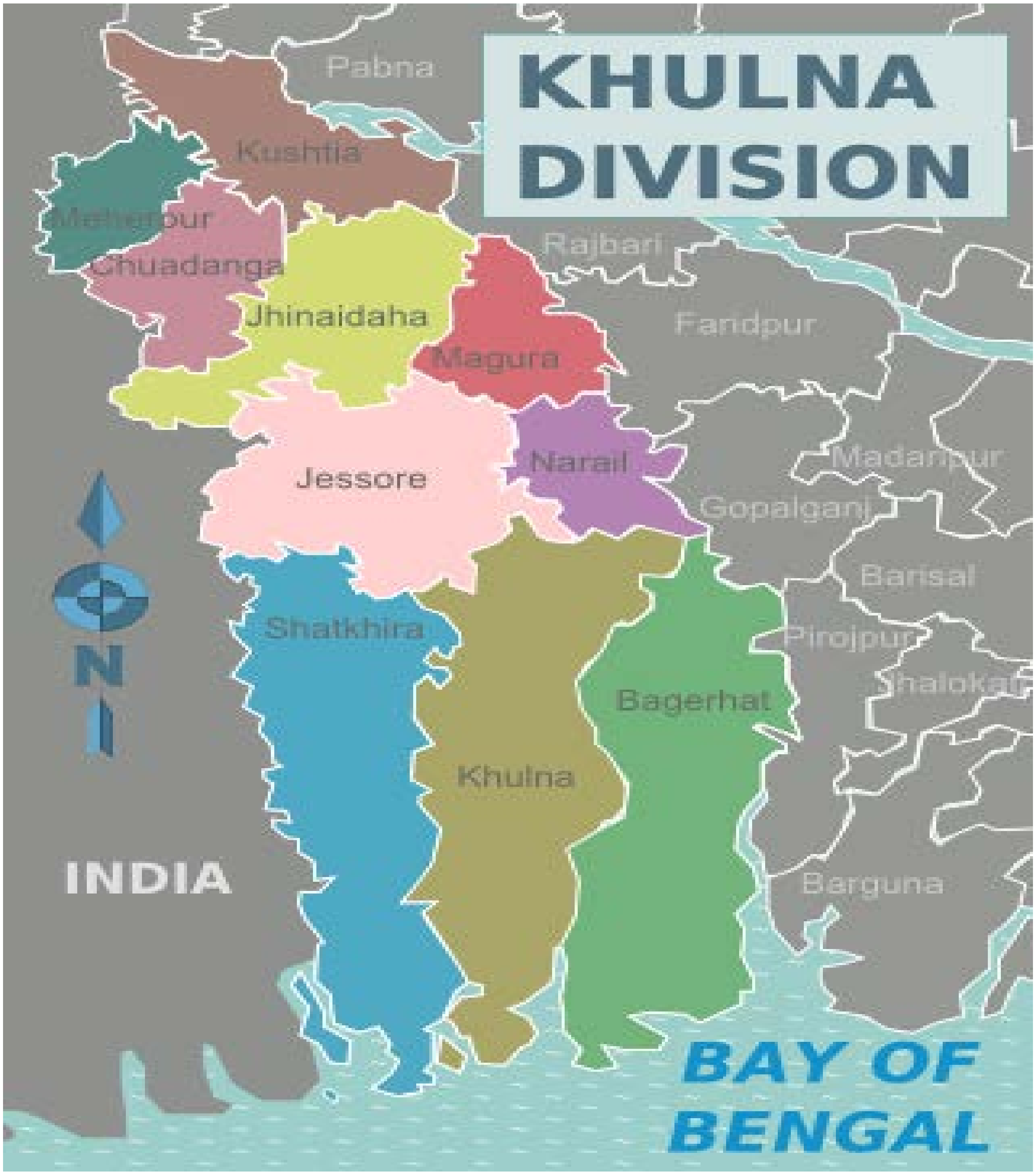


Figure 3.1 Map of Khulna division

The population of Khulna City Corporation is about 1.5 million with a density of 32,859 persons per square km. There are 31 wards with 66,257 holdings. Khulna Water Supply and Sewerage Authority were established in 2008 to provide water and sanitation facilities within the city, but so far they have been focusing only on increasing residents' access to water. The importance of Khulna City has increased significantly with the beginning of construction of the Padma Bridge at Mawa. The bridge will drastically reduce travel time with the capital and also promote activities of the Mongla seaport.

Kushtia Municipality

Kushtia Municipality is a Class 'A' Municipality with 21 wards, of which its jurisdiction has been recently extended to cover part of an additional two unions. Therefore, the extended area encompasses 27.8 square km. The population of Kushtia (with extended) is 238,065 and there are 27,093 holdings. The northern and eastern periphery of the municipality is flanked by two rivers, the Gorai and Kaliganga, respectively.

This town has long been renowned as a trading and manufacturing hub, administrative centre and cultural melting-pot. Kushtia Paurashava, as the word, 'Municipality' is commonly known in Bangla, has received its municipal status on April 1, 1869. This municipality falls under Kushtia District which is bounded by Rajshahi, Natore and Pabna districts on the north, Chuadanga and Jhenaidah districts on the south, Rajbari district on the east, Paschim Banga (West Bengal) of India and Meherpur district on the west. Padma, Garai, Mathabhanga, Kumar are the main rivers of this region.

Jhenaidah Municipality

Jhenaidah Municipality is a Class 'A' Municipality with 9 (nine) wards and an area of 32.4 square km. The population of Jhenaidah is 157,822 with a density of 3,987 per square km. There are 13,390 holdings. There is only one river in Jhenaidah, the Nabaganga. Jhenaidah is a small town. The surroundings districts are Chuadanga, Magura, Jessore, Kushtia and Rajbari.

3.3 Methodology of the Study

The chronological activities of this study are delineated as below:

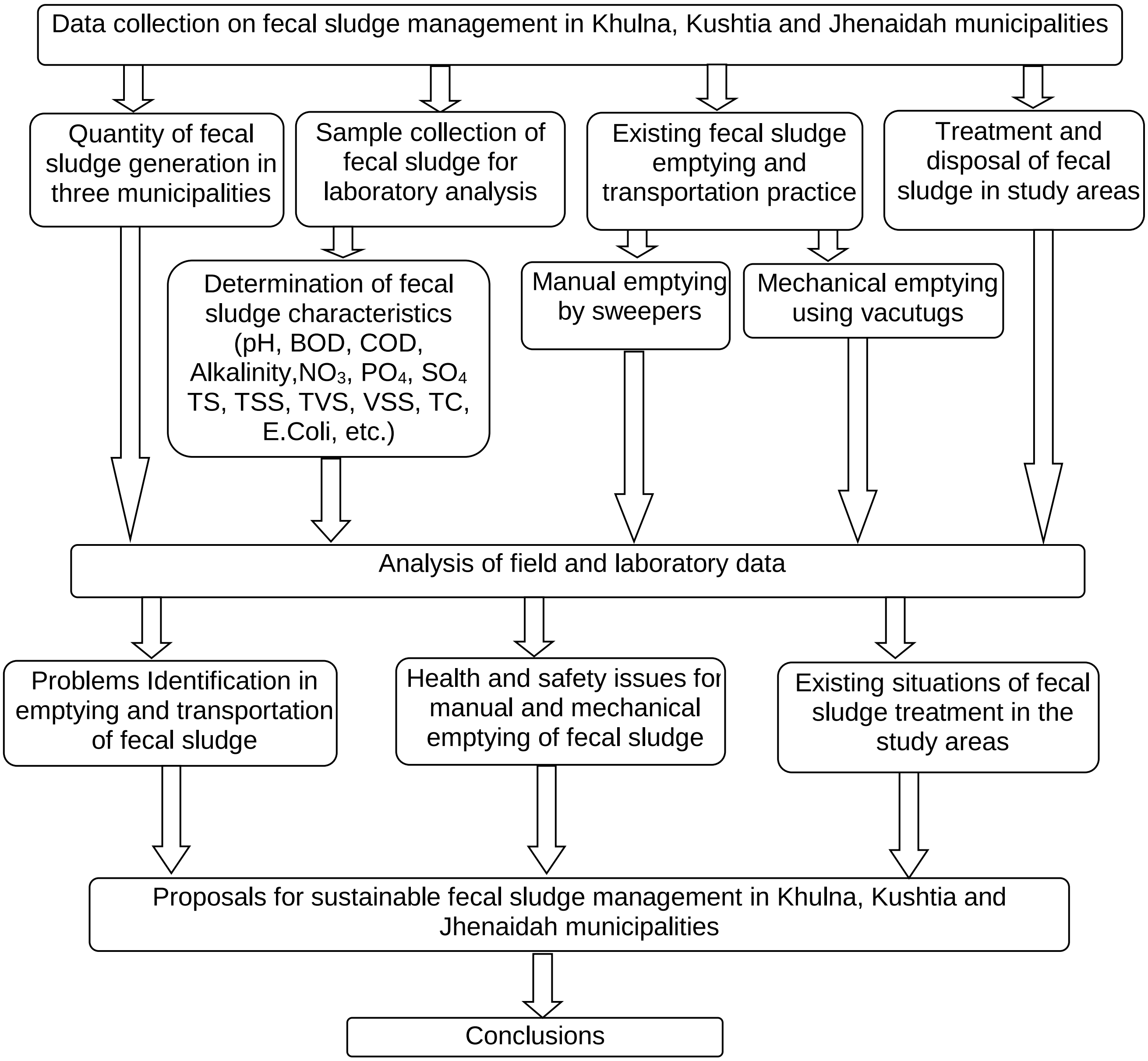


Figure 3.2: Flowchart showing the sequential steps in the research work

3.3.1 Literature Review

An intensive literature review was undertaken to acquire the knowledge on Fecal Sludge Management in Bangladesh and abroad. The relevant data and information reviewed from various reports and research studies have been included in Chapter II of this thesis report. Also, the initiatives and program taken by both the Government of Bangladesh and the NGOs for FSM in Bangladesh was quoted in the same chapter captioned as "Literature Review".

3.3.2 Visual Inspection

Visual inspection was carried out to assess the practical condition of the study area regarding FSM issues. It also helps to identify the impacts of various interventions to the existing situations. Several times visit were required for visual inspection and to perform other related tasks under the research study.

3.3.3 Data Collection

Data collection had been done to identify the existing conditions of FSM in the selected municipalities namely Khulna City Corporation, Kushtia Municipality and Jhenaidah Municipality under the study area. Data of entire system of fecal sludge management such as user interface, storage/containment, emptying, collection, transportation, treatment, disposal and reuse were collected from respective personnel and department of these three municipalities and also from relevant agencies and individuals working in this sector.

3.3.4 Determination of quantity of fecal sludge generation

Quantity of fecal sludge has been determined with the data getting from baseline survey. Two methods have been applied here. One is using baseline data of the number of toilets with septic tank and pit toilets. Another one is with the number of total population of the city.

3.3.5 Fecal Sludge Sampling

Samples of fecal sludge were collected from these three municipalities during 2015. Samples were collected from 8 different locations and different types of containment. The Fecal Sludge has been collected from different pits/septic tank in the different areas of the cities. Fecal sludge of septic tank and the pits were stirred and the samples were collected.

3.3.6 Methods of analysis

There are a number of tests parameters for FS standards mentioned in the table 3.2. In the study some common and important test parameters have been conducted in context of locality at the environmental laboratory of KUET. All the test parameter have been determined as per standard method (APHA, 1998) and HACH recommended method of wastewater analysis as there is no standard method for fecal sludge analysis. The parameters included all types of test like physical, chemical and bacteriological parameters. The test parameters with respective test information are presented in the table 3.2 as follows:

Table 3.1: FS quality test methods

Type of test	**Water Quality Parameters**	***Standard Methods (SM) of Wastewater Analysis**
Physical Test	Temperature	SM 2550 B
	Sludge Volume Index (SVI)	SM 2710 D
	Total Solids (TS)	SM 2540 B
	Total Suspended Solids (TSS)	SM 2540 D
	Total Volatile Solids (TVS)	SM 2540 E
	Volatile Suspended Solids (VSS)	SM 2540 E
Chemical Test	pH	SM 4500-H^+ B
	Biochemical Oxygen Demand (BOD_5)	SM 5210 B
	Chemical Oxygen Demand (COD)	SM 5220 C
	Iron (Fe)	SM 3500-Fe B
	Nitrate (NO_3)	SM 4500-NO_3^- E
	Phosphate (PO_4)	SM 4500-P E
	Electrical Conductivity (EC)	SM 2510 B
	Total Alkalinity (as $CaCO_3$)	SM 2320 B
Bacteriological Test	Total Coliform (TC)	SM 9222 B
	Escherichia Coliform (E.Coli.)	SM 9222 D

**Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF)*

CHAPTER IV

FSM SCENARIO IN THREE MUNICIPALITIES

4.1 General

The complete value chain of Fecal Sludge Management (FSM) includes the components of user interface or toilets, containment, collection and transportation, treatment and enduse have been thoroughly investigated in three municipalities of the study area. The data have been reviewed from sample size 4404 of Khulna City, 1255 of Kushtia municipality and 1000 of Jhenaidah municipality. The data collected from field and determined in laboratory have been thoroughly analyzed. Moreover, health and safety issues are investigated. Thus, each of the components of value chain has been analyzed and problems have been identified.

4.1.1 Basic information

Table 4.1: Basic information of three municipalities

Description	**Khulna**	**Kushtia**	**Jhenaidah**
Year of establishment	6 August 1990	1 April,1869	11-03-1958
Area	45.65 km2	42.79 sq.km	32.42 SqKm
Population	15,00,689	3,75,149	157822
Population Density	67,994 per km^2.		
No of wards	31	21	32,215
Total length of drains	642.18 km	260 km.	
No of Holding	66257		13530
Solid Waste Generation and Disposal per day	450 M.Tons (Av)		

(Source: Basic Statistics of KCC, Kushtia and Jhenaidah, 2016)

4.1.2 Household Size and Population

Khulna is first in terms of household size, with nearly five and one-third persons per household, followed by Jhenaidah with slightly less than that. The average household size in all of the study areas is higher than the average national household size for urban areas which is 4.29 (BBS, 2011).

Table 4.2: Average household size

	Khulna	Kushtia	Jhenaidah
Mean	5.32	4.86	5.29
Median	5	4	5
Mode	4	4	4

Area-wise Khulna City Corporation and Kushtia Municipality are almost same but Khulna city is four-times populated than Kushtia Municipality. However, the land area of Jhenaidah is about three-fourth of KCC while the population is around one-tenth only.

4.1.3 Wealth Quintiles of Study Areas

Table 4.5 presents the wealth quintiles of slum and non-slum households in the study areas. More than 85% of households residing in slum areas of Khulna and Kushtia are in the bottom two quintiles, compared with about one-third in non-slum areas. Among the three cities, Jhenaidah has the highest number of poorest population in slum areas. The data also reveals that about 10-12% of slum dwellers have better wealth conditions in Khulna and Kushtia.

Table 4.3: Population by wealth quintiles (in percent)

Wealth Quintile	Non-Slum			Slum		
	Khulna	Kushtia	Jhenaidah	Khulna	Kushtia	Jhenaidah
Poorest	14.53	13.58	16.49	52.92	60.47	100
Poor	17.17	19.14	20.88	37.34	26.16	0
Medium Wealth	22.66	21.88	20.88	3.73	7.56	0
Wealthy	22.53	22.97	20.88	4.71	1.74	0
Wealthiest	23.06	22.42	20.88	1.3	4.07	0

(Source: FSM Survey, 2014)

Wealth quintile of three cities: In non-slum areas, all classes of population are living. But in slum areas, poor population are predominantly living. In Jhenaidah, the poorest population are more than those of Khulna and Kushtia.

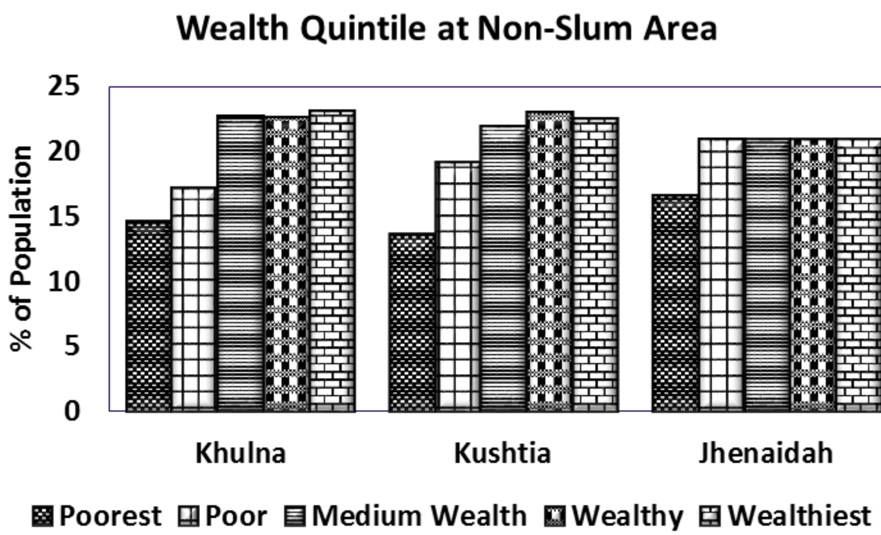


Figure 4.1: Non-Slum Wealth Quintile

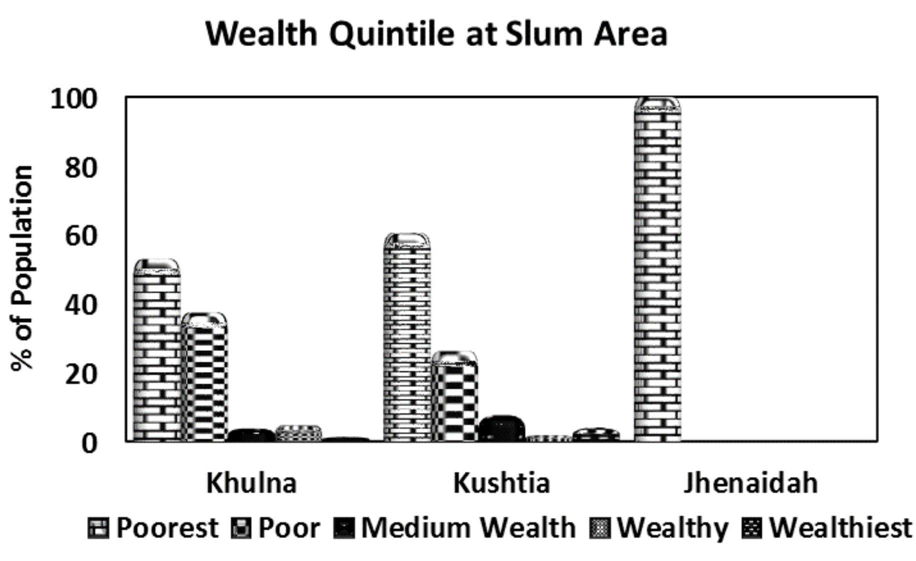


Figure 4.2: Slum Wealth Quintile

4.2 Sanitation Situation in Study Area

4.2.1 Types of Toilets

Toilets with a septic tank are predominant in all three cities, but in most households in Khulna and Kushtia the tanks act as containment only, because soak wells are non-existent. Only Kushtia has a sewerage network (wards 6 & 7), which covers 4% of the population, but this network is not connected to any treatment plant. Instead, faecal sludge is being disposed directly into waterbodies. Types of toilets in Khulna households range from the most unhygienic (a hanging toilet) to toilets connected to a Decentralized Wastewater Treatment System (DEWATS). In addition to hanging latrines (present in less than 1% of households), unimproved toilets also include direct open pit without cover (1.4%) and latrines connected directly to drains or open space, i.e. no containment (8.1%). There are more types of toilets used in Khulna than in Kushtia and Jhenaidah.

Figure 4.3: Pit toilet superstructure and inside condition in Kushtia

More than half of the pit latrines in Kushtia are two pit latrines without a Y-junction. This indicates a lack of understanding on the principles and benefits of proper twin pit latrines with a Y-junction. Households could not utilize the benefits of resource recovery from the technology. The variance in knowledge and practice for resource recovery and use is very high. Most individual households have their own toilet. However, very few of them are environmentally safe. About 35% of households in Jhenaidah use an environmentally safe toilet as there are many households with a functional soak well. The situation is worse in Khulna (only 4%) and Kushtia (13%).

Figure 4.4: Hanging toilet in KCC

Most households have access to an improved toilet with water-seal and inaccessible to flies (Khulna 66.09%, Kushtia 63.51% and Jhenaidah 43%). It was found that open defection has been very low in all three cities (Khulna 1.33%, Kushtia 1.10% and Jhenaidah 1.9%).

Table 4.4: Types of toilets in three cities

Types of toilet	Khulna		Kushtia		Jhenaidah	
	Count	Percent	Count	Percent	Count	Percent
Hanging latrine	4	0.1%				
Direct open pit/pit without cover	59	1.4%	2	0.2%	21	2.1%
Latrine connected to open space or drain	351	8.1%	11	0.9%	19	1.9%
Don’t know where it goes after flush	34	0.8%			6	0.6%
Bucket latrine	2	0%			6	0.6%
Covered pit latrine	227	5.3%	9	0.7%	22	2.2%

Pit latrine with covered slab and pan	930	21.6%	509	40.6%	460	46.9%
Ventilated Improved Pit latrine	42	1.0%	46	3.7%	1	.1%
Septic tank	2,660	61.7%	629	50.1%	446	45.5%
Sewerage system			49	3.9%		
Total	**4,309**	**100.0%**	**1,255**	**100.0%**	**981**	**100.0%**

The majority of toilets have either a septic tank or pit as containment, but due to a lack of proper design and installation of these technologies – and no collection and treatment facilities – almost all faecal sludge is being disposed into waterbodies.

Table 4.51: Types of pit latrines

Types of toilet	Khulna		Kushtia		Jhenaidah	
	Count	**Percent**	**Count**	**Percent**	**Count**	**Percent**
Direct Single Pit	266	22%	46	8%	280	58%
Offset Single Pit	192	16%	73	13%	140	29%
Double Pit without Y-Junction	459	38%	309	55%	0	0%
More Than Two Pits	122	10%	31	5%	54	11%
Twin Pit with Y-Junction	160	13%	105	19%	9	2%
Total	**1199**	**100.0%**	**564**	**100.0%**	**483**	**100.0%**

4.2.2 Shared toilets

Shared toilets are categorised as unimproved as per definition in the Joint Monitoring Programme (JMP of WHO/Unicef, 2015).

In Khulna 45% of households living in slums located on private land are using a shared toilet while in Kushtia and Jhenaidah the proportion is 30% and 12%, respectively. More than one-third of the households living in slums located on government land are using a shared toilet.

4.3 Containment

Ideally, a septic tank to be connected with a soak well/pit or a leach field where there is no sewerage network. Below information found in the field has been compared with this ideal one.

In Khulna, Kushtia and Jhenaidah 7.4%, 27.8% and 80.3% septic tanks have soak-well, respectively. Alternatively, 84.0%, 68.3% and 15.7% septic tank has no soak well. With these data analysis, we can come to conclude that the bigger the town, the problem is more than small towns.

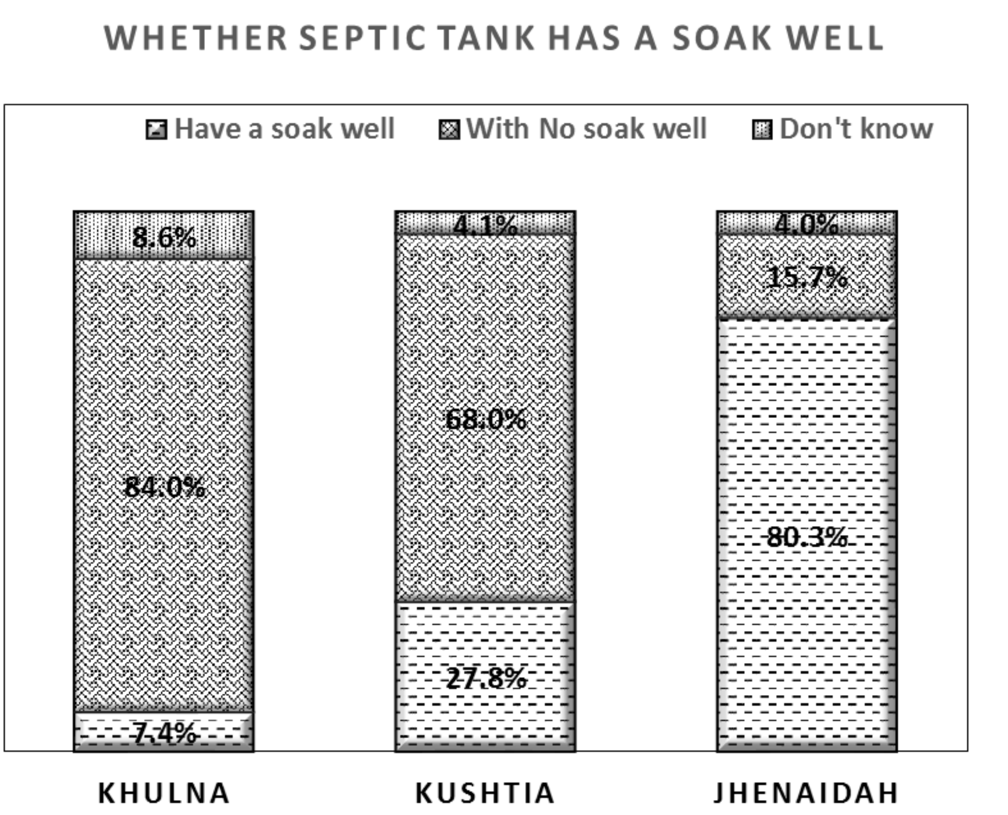


Figure 4.5: Septic tank with or without soak well

In Khulna, Kushtia and Jhenaidah, there are 27%, 16% and 21% HHs, respectively built their septic tank together with building construction. On the other hand, 59%, 77% and 72% of HHs in Khulna, Kushtia, respectively did not build septic tank/pit together with building.

4.3.1 Connection of septic tanks to drains or surface water

In Khulna and Kushtia, 84% and 68% of households, respectively have septic tanks connected to drains or surface water; these households comprise 52% and 34% of the total households, respectively that have a toilet. 94% of households whose septic tanks are not connected to a soak well/pit in Khulna mentioned that septic tank outlets were connected to surface or grey water drain. Another 4% mentioned that effluent from the septic tank is released onto open ground. In Jhenaidah, 80% of households having a septic tank also have a soak well. The main reason for not having a soak well in Khulna and Kushtia is because both cities have high water tables and a soak well does not work and availability of drains.

Figure 4.6: Septic tank connected to open ground

4.3.2 Households with/without septic tank/pit

It is alarming that more than 75% of households in Kushtia and 72% of households in Jhenaidah did not build their septic tanks along with the building. The percentage is much lower in Khulna. The reason for this difference may lie in the varying degree of compliance to building construction regulations as well as the age of the city. At city corporation level, incorporating a septic tank into building design is a prerequisite for approval of any new construction plan. People in Kushtia and Jhenaidah might not be aware of the system, or strict regulations imposed by Paurashavas may not be enforceable.

Table 4.6: HHs who built their septic tank/pit together with/without the building

Issue	Khulna		Kushtia		Jhenaidah	
	No.	%	No.	%	No.	%
Septic tank/pit built together with building	1039	26.9	193	15.5	197	21.2
Septic tank/pit not built together with building	2262	58.6	955	76.9	668	71.8
Don’t Know	558	14.5	94	7.6	65	7.0

4.4 Quantity of fecal sludge generation in the study areas

In Khulna, Fecal Sludge generation per year was found to be 7,21,213 m^3 and 7,10,000 m^3 theoretically and practically, respectively. In Kushtia municipality, practical and theoretical estimation were 1,04,581 and 1,09,527 m^3/year, respectively. In Jhenaidah, volumes of faecal sludge were 58,705 and 68,078 m^3/year from field survey and theoretical estimation. In Khulna, FS generation is seven-times more than Kushtia. In Jheniadah it is very less. Estimation and supporting references are shown in Appendix 1.

Assumptions:

a. Average emptying of ST/Pit within (0~3) years => 1.5 years and Over 3 years => 5 years.

b. In calculating theoretical market size, it is assumed that pit and ST are being filled in @ 0.3 ltr per person per day and 0.7 ltr per person per day, respectively.

Table 4.7 Reported faecal production rates

Location	Wet weight (g/person/day)
high income countries[1]	100-200
low income countries, rural[2]	350
low income countries , urban[2]	250
China[3]	315
Kenya[4]	520
Thailand[5]	120-400

- **Location Wet weight (g/person/day)**
- [1] Lentner *et al.* (1981); Feachem *et al.* (1983); Jönsson *et al.* (2005); Vinnerås *et al.* (2006), [2] Feachem *et al.* (1983), [3] Gao *et al.* (2002), [4] Pieper (1987), [5] Schouw *et al.* (2002)

Sample Calculation for KCC:

Total number of ST emptied (annually) = 1,85,800x(0.03/1.5) + 1,85,800x(0.97/5) = 39,761

Total number of Pit emptied (annually) = 1,15,335 x (0.03/1.5) + 1,15,335 x (0.97/5) = 24,682

Fecal Sludge Volume (Actual Field Survey) = 39,761x16.64m3 + 24,682x1.96 m3 = 7,10,000 m3

Fecal Sludge (Theoretical) = (1,85,800x12x0.7/1000x365)m3 + (1,15,335x12x0.3/1000x365)m3 = 7,21,213m3

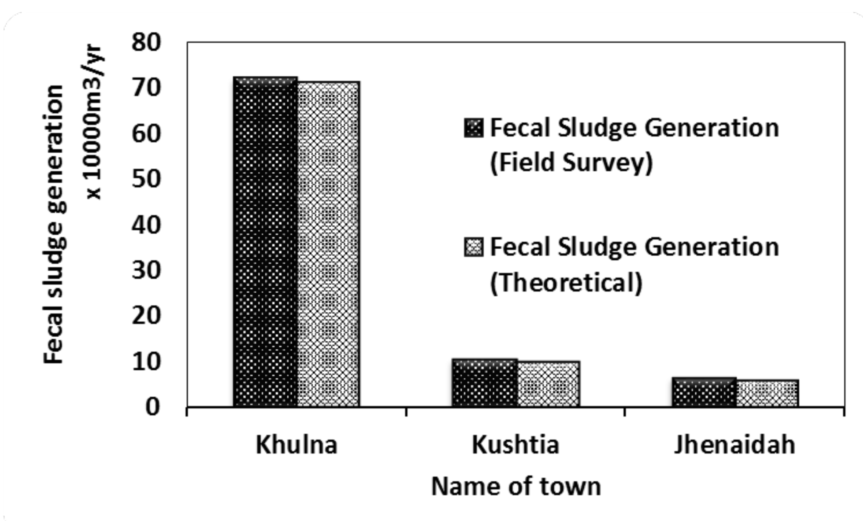


Figure 4.7: Quantity of fecal sludge generation annually in Khulna, Kushtia and Jhenaidah

4.5 FS Sampling

Samples of fecal sludge were collected from these three municipalities during 2015. Samples were collected from 8 different locations and different types of containment. The Fecal Sludge has been collected from different pits/septic tank in the different areas of the cities. The manhole/cover of the septic tanks/pits were opened, then it was stirred the fecal sludge with long bamboo stick and the samples were collected into the plastic jar using a bucket. So, all were mixed samples. The details of the samples are described in the below table:

Table 4.8: Samples from different area and source

Name of the city	Sample from the area	Sample source
Khulna City	Siddikia Madrasha Hostel, Ward 18	Septic Tank
	Raligate Household, Ward No. 1	Pit Latrine
Kushtia municipality	Fazlur Rahman, Thana Para, Ward No. 2	Septic Tank
	Mr. Jhontu, Aruapara, Ward No. 9	Pit Latrine
	Housing Colony, Ward No. 6	Septic Tank
Jhenaidah Municipality	Sweeper Colony, Ward No. 7	Septic Tank
	Ayesha Nurse, Ward No. 4	Septic Tank
	Sweeper Colony, Ward No. 2	Pit Latrine

Figure 4.8: Sample collection from a septic tank

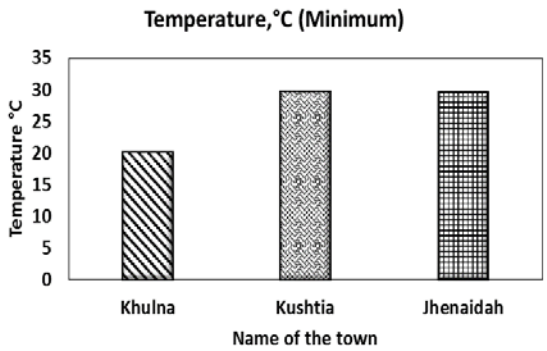
4.5.1 Fecal sludge characteristics

The samples have been collected from different locations of each city and tests have been done in Environmental Engineering Laboratory at KUET. A total 16 wastewater quality parameters were tested in the laboratory for each of the fecal sludge samples collected from the three cities. The test parameters are mentioned in the table 4.10.

Figure 4.9: Laboratory analysis of FS at KUET Lab (Training & Works)

Wastewater quality parameters that have been considered for the characterization of fecal sludge include: solids concentration, chemical oxygen demand (COD), biochemical oxygen demand (BOD), nutrients, pathogens, etc. These parameters are the same as those considered for domestic wastewater analysis, however, it needs to be emphasized that the characteristics of domestic wastewater and FS are very different. Graphical representation of the test results of the parameters are shown below:

Temperature: The minimum Temperature in fecal sludge of Khulna, Kushtia and Jhenaidah are 21.1, 29.7 and 29.6 ^{o}C, respectively while the maximum are 24, 30 and 30 ^{o}C, respectively. Limits for Disposal in Water Bodies (ECR'97, Bangladesh) is only 30^{o}C.



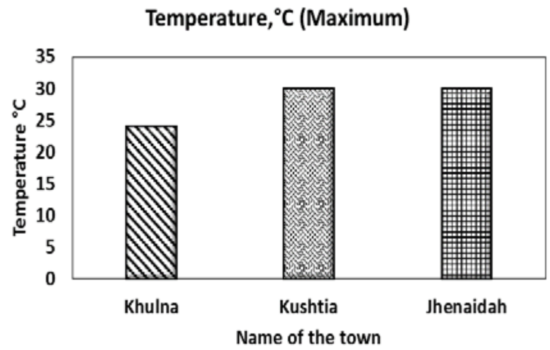
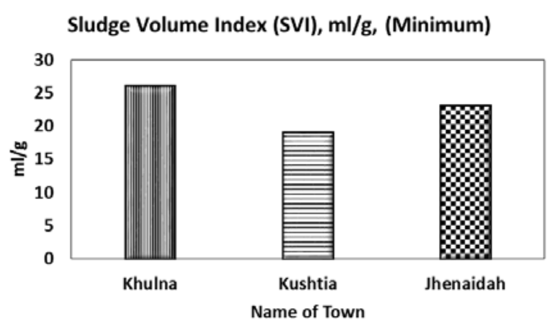


Figure 4.10a: Temperature (Minimum) **Figure 4.10b:** Temperature (Maximum)

SVI: The minimum Sludge Volume Index (SVI) in fecal sludge of Khulna, Kushtia and Jhenaidah are 26, 19 and 23 ml/g respectively while the maximum are 33, 27 and 25 ml/g respectively in three towns.



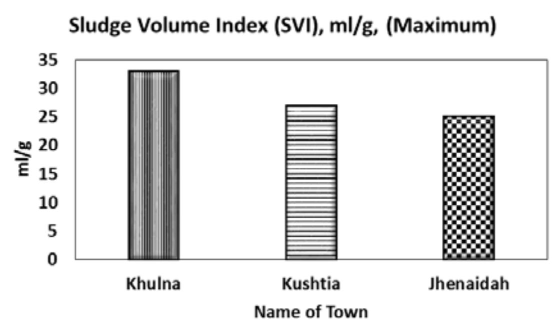


Figure 4.11a: SVI (Minimum) **Figure 4.11b:** SVI (Maximum)

Total Solids: The minimum Total Solids (TS) in fecal sludge of Khulna, Kushtia and Jhenaidah are 38920, 38400 and 41380 mg/L respectively while the maximum are 44560, 54410 and 58890 mg/L respectively in three towns.

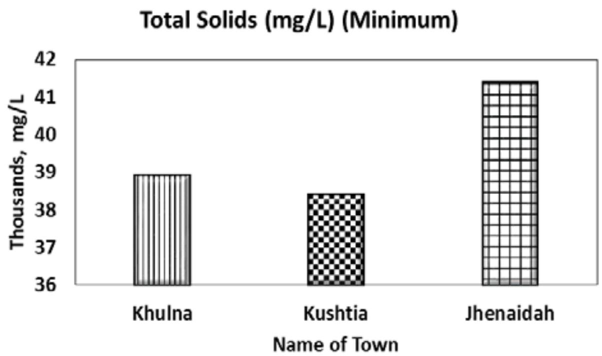


Figure 4.12a: TS (Minimum)

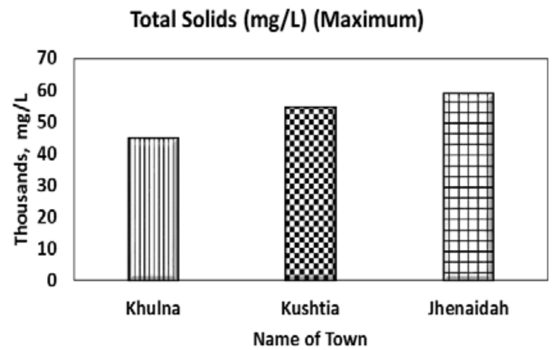


Figure 4.12b: TS (Maximum)

The Solid contents in Fecal Sludge were found to be varied between 3% to 6% for all three study areas. Total Solids (TS) in fecal sludge of Pit latrines in Khulna, Kushtia and Jhenaidah were found to be 3.9%, 3.8% and 5.9%, respectively while those were 4.5%, 5.4% and 4.6%, respectively for septic tanks. Thus, almost similar quantities of total solids were found for both septic tanks and pit latrines.

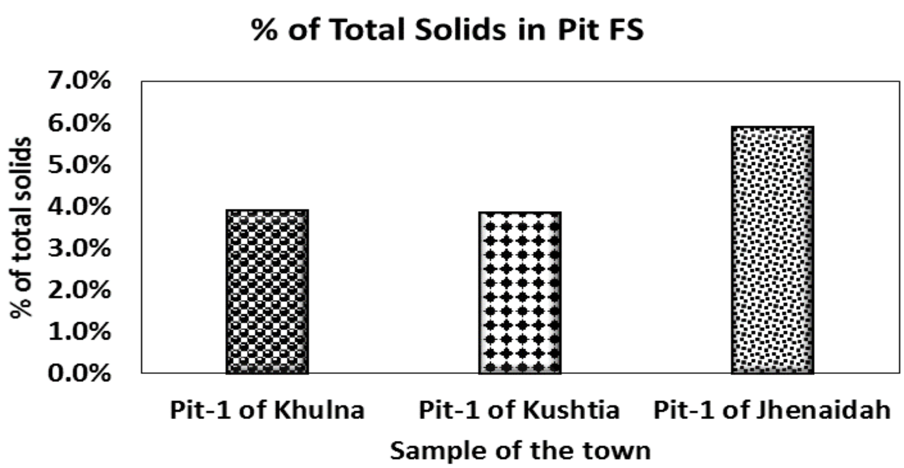


Figure 4.13a: Percentage of Total Solids in Pit

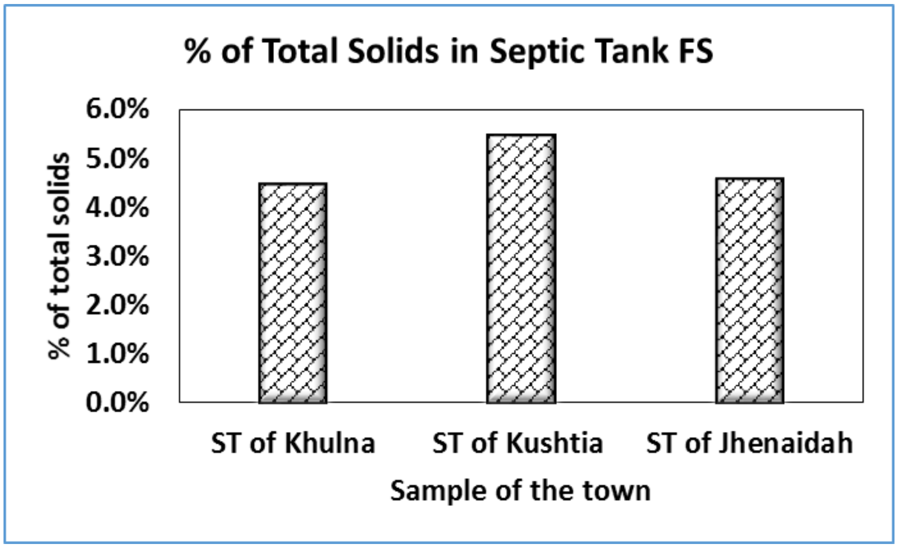


Figure 4.13b: Percentage of Total Solids in Septic Tank

TSS: The minimum Total Suspended Solids (TSS) in fecal sludge of Khulna, Kushtia and Jhenaidah are 29650, 35360 and 39540 mg/L, respectively while the maximum are 30060, 52730 and 56710 mg/L respectively in three towns. Limits for Disposal in Water Bodies (ECR'97, Bangladesh) is only 100 mg/L.

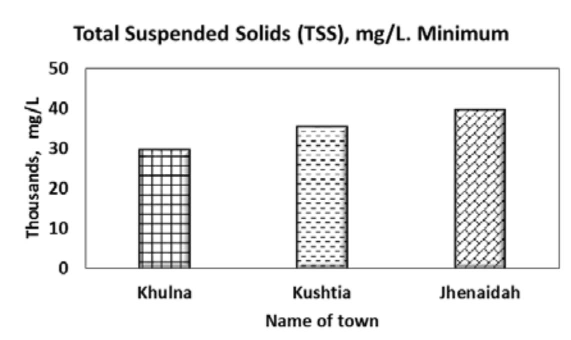


Figure 4.14a: TSS (Minimum)

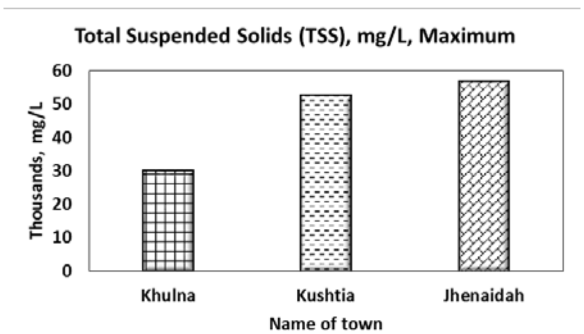


Figure 4.14b: TSS (Maximum)

TVS: The minimum Total Volatile Solids (TVS) in fecal sludge of Khulna, Kushtia and Jhenaidah are 19460, 31980 and 32630 mg/L respectively while the maximum are 27980, 47570 and 47360 mg/L, respectively in three towns.

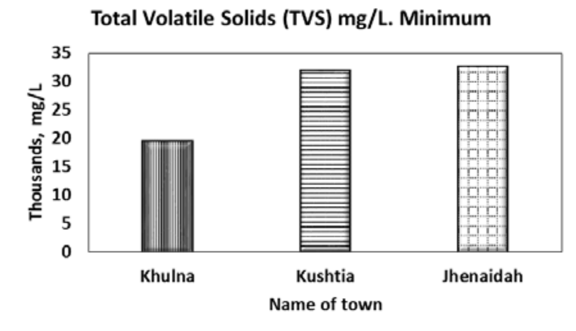


Figure 4.15a: TVS (Minimum)

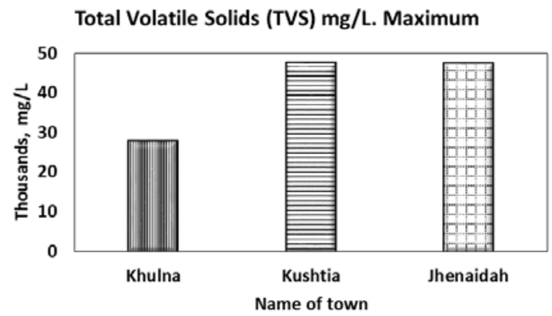


Figure 4.15b: TVS (Maximum)

VSS: The minimum Volatile Suspended Solids (VSS) in fecal sludge of Khulna, Kushtia and Jhenaidah are 22240, 27220 and 29580 mg/L respectively while the maximum are 22545, 39170 and 41250 mg/L, respectively in three towns.

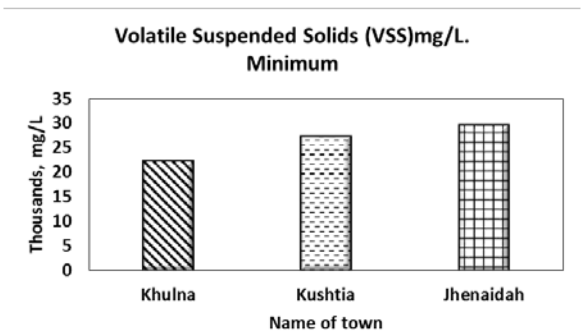


Figure 4.16a: VSS (Minimum)

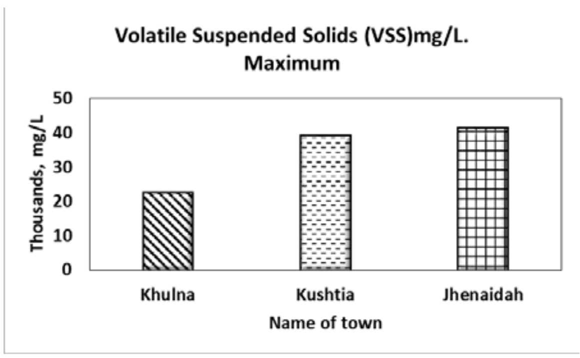
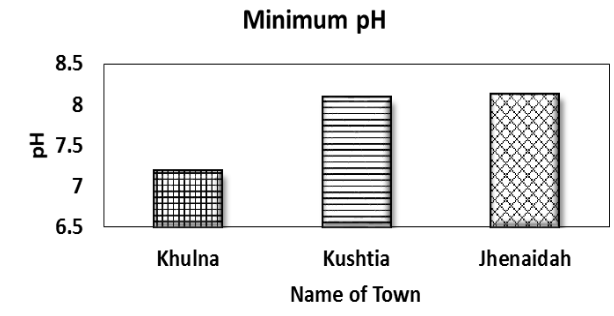


Figure 4.16b: VSS (Maximum)

pH: pH in fecal sludge of Khulna is less than this of other two towns, but more than 7.0. The minimum pH in Khulna, Kushtia and Jhenaidah are 7.19, 8.09 and 8.13 respectively while the maximum pH are 7.44, 8.19 and 8.19, respectively.



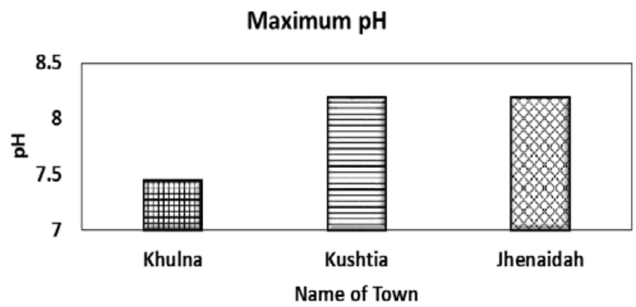
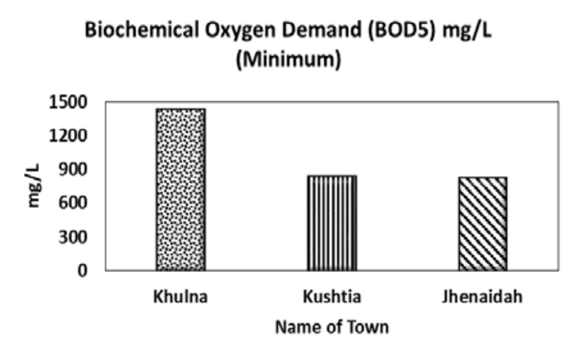


Figure 4.17a: pH (Minimum) **Figure 4.17b:** pH (Maximum)

BOD_5: The minimum Biochemical Oxygen Demand (BOD_5) in fecal sludge of Khulna, Kushtia and Jhenaidah were found to be 1434, 834 and 819 mg/L, respectively while the maximum were 1662, 1422 and 1110 mg/L, respectively in three municipalities. However, the standard limit (ECR) for disposal into inland water bodies is only 40 mg/L. Thus, this is the challenge to reduce the BOD load in treatment plant. Based on 256 raw septage samples taken from April 1997 to May 2003 BOD5 were 2300 mg/L (Average), 630 mg/L (minimum) and the maximum were 13500 mg/L (Source: Koottatep et al (2005)].



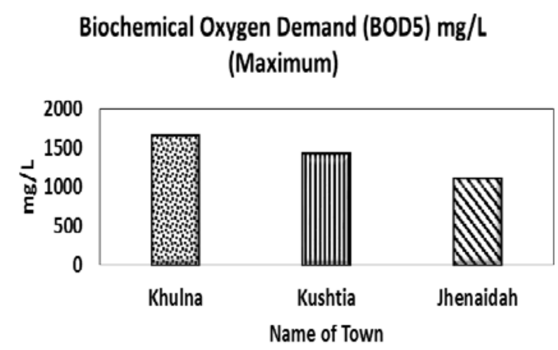
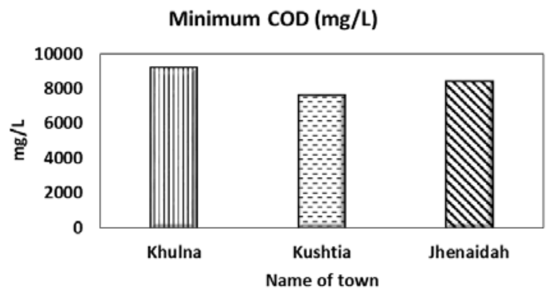


Figure 4.18a: BOD_5 (Minimum) **Figure 4.18b:** BOD_5 (Maximum)

COD: The minimum Chemical Oxygen Demand (COD) in fecal sludge of Khulna, Kushtia and Jhenaidah are 9200, 7600 and 8400 mg/L, respectively while the maximum are 9600, 8800 and 8800 mg/L, respectively in three towns. There is no standard of ECR for wastewater disposal in waterbodies. Based on 256 raw septage samples taken from April 1997 to May 2003 COD were 15700 mg/L (Average), 1108 mg/L (minimum) and the maximum were 76075 mg/L (Source: Koottatep et al (2005)].



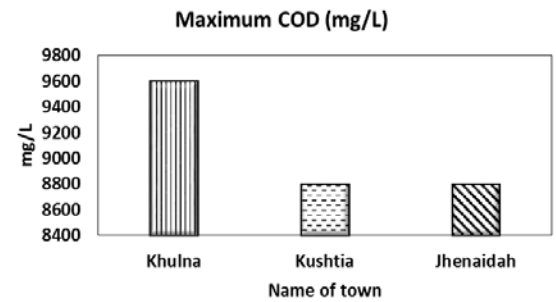
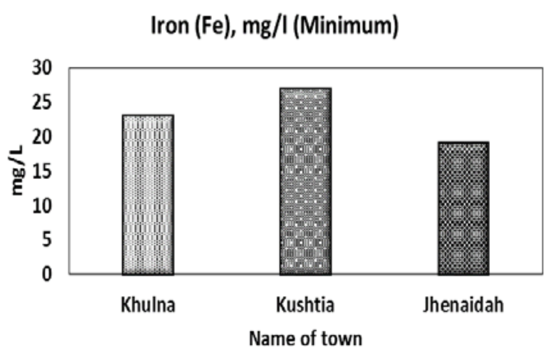


Figure 4.19a: COD (Minimum) **Figure 4.19b:** COD (Maximum)

Fe: The minimum Iron (PO_4) content in fecal sludge of Khulna, Kushtia and Jhenaidah are 23, 27 and 19 mg/L, respectively while the maximum are 48, 36 and 39 mg/L, respectively in three towns.



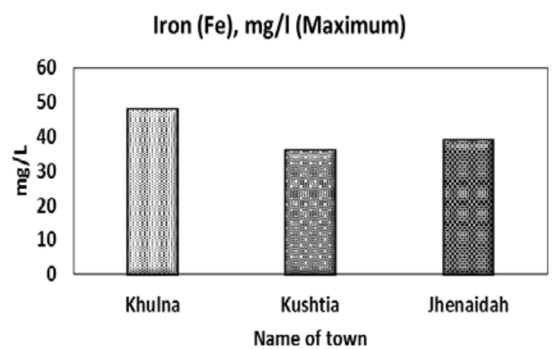
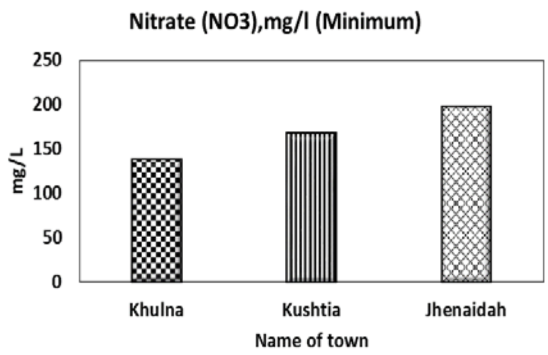


Figure 4.20a: Fe (Minimum) **Figure 4.20b:** Fe (Maximum)

NO_3: The minimum Nitrate (NO_3) in fecal sludge of Khulna, Kushtia and Jhenaidah are 138, 168 and 198 mg/L, respectively while the maximum are 270, 270 and 390 mg/L, respectively in three towns. Limits for Disposal in Water Bodies (ECR’97, Bangladesh) is 250 mg/L.



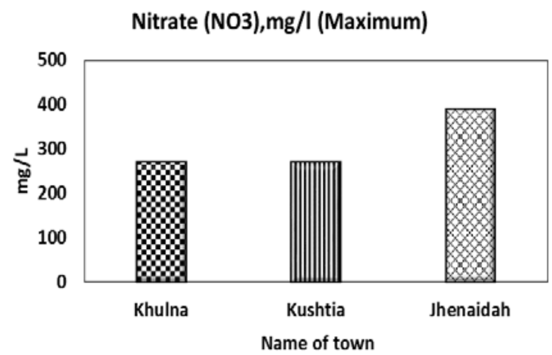
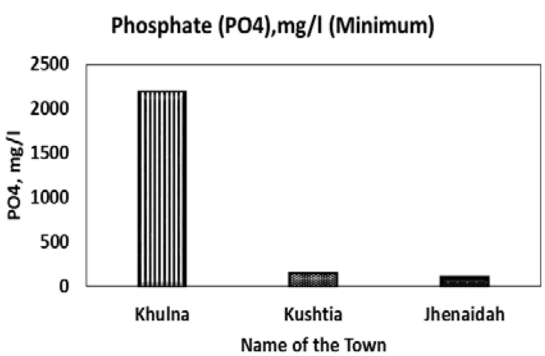


Figure 4.21a: NO_3 (Minimum)

Figure 4.21b: NO_3 (Maximum)

PO_4: The minimum Phosphate (PO_4) in fecal sludge of Khulna, Kushtia and Jhenaidah are 2184, 147 and 105 mg/L, respectively while the maximum are 2808, 1527 and 171 mg/L, respectively in three towns. Huge difference in nutrient of Phosphate found here in Kushtia and Jhenaidah with Khulna. Limits for Disposal in Water Bodies (ECR'97, Bangladesh) is only 35 mg/L.



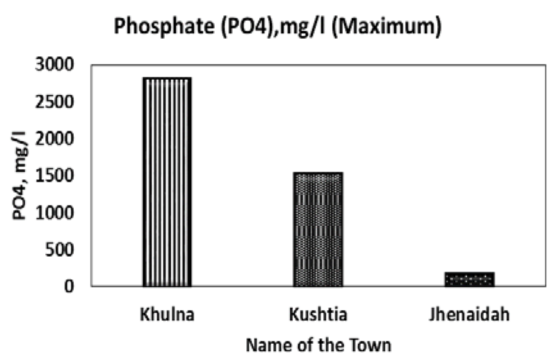
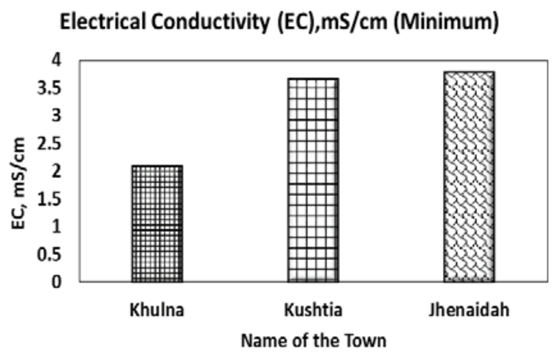


Figure 4.22a: PO_4 (Minimum)

Figure 4.22b: PO_4 (Maximum)

Electrical Conductivity: The minimum Electrical Conductivity (EC) content in fecal sludge of Khulna, Kushtia and Jhenaidah are 2.08, 3.66 and 3.78 mS/cm, respectively while the maximum are 3.66, 5.96 and 4.33 mS/cm, respectively in three towns.



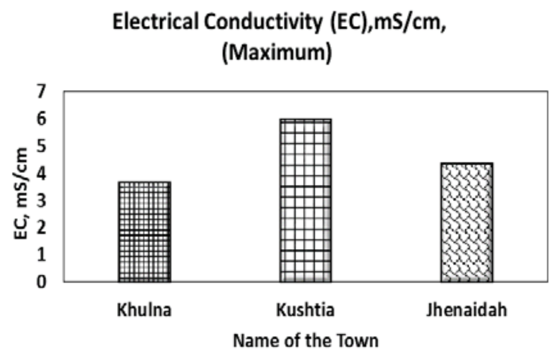
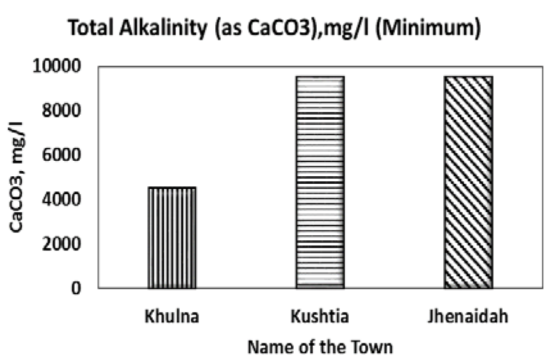


Figure 4.23a: EC (Minimum)

Figure 4.23b: EC (Maximum)

Total Alkalinity: The minimum Total Alkalinity (as $CaCo_3$) content in fecal sludge of Khulna, Kushtia and Jhenaidah are 4500, 9500 and 9500 mg/L, respectively while the maximum are 10500, 14000 and 10500 mg/L, respectively in three towns.



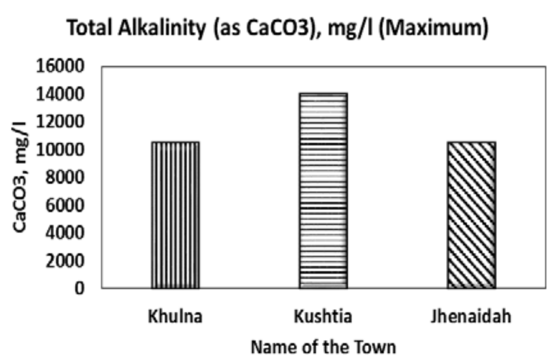


Figure 4.24a: Total Alkalinity (Minimum) **Figure 4.24b:** Total Alkalinity (Maximum)

Total Coliform: The minimum Total Coliform (TC) in fecal sludge of Khulna, Kushtia and Jhenaidah are 168000, 152000 and 170000 N/100ml, respectively while the maximum are 444000, 230000 and 231000 N/100ml, respectively in three towns.

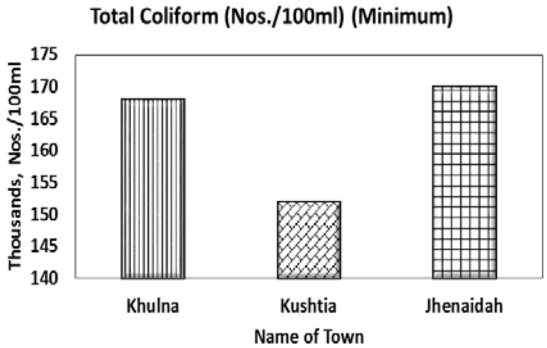


Figure 4.25a: Total Coliform (Minimum)

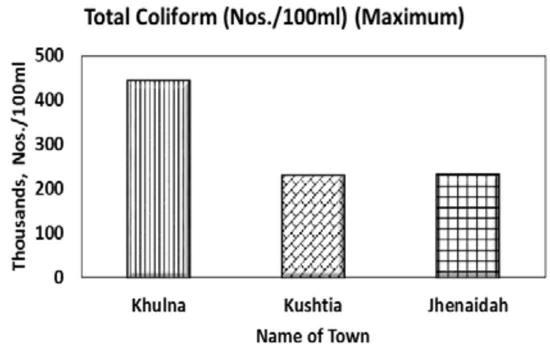


Figure 4.25b: Total Coliform (Maximum)

Escherichia Coliform: The minimum Escherichia Coliform (E.Coli.) in fecal sludge of Khulna, Kushtia and Jhenaidah are 117000, 121000 and 110000 N/100ml, respectively while the maximum are 390000, 170000 and 196000 N/100ml, respectively in three towns. Limits for Disposal in Water Bodies (ECR'97, Bangladesh) is only 1000 N/100ml.

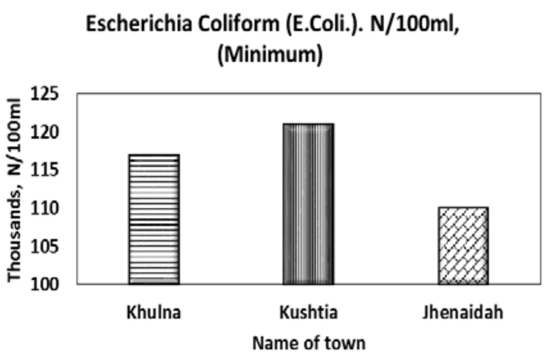


Figure 4.26a: E. Coli (Minimum)

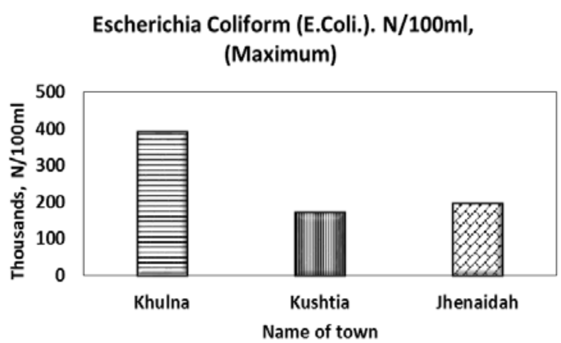


Figure 4.26b: E. Coli (Maximum)

4.5.2 Summary Results of FS Quality Parameters

Table 4.9: Test results of laboratory analysis of fecal sludge

Sl. No.	Water Quality Parameters	Units	Test Results			Limits for Disposal in Water Bodies (ECR'97, Bangladesh)
			Khulna	Kushtia	Jhenaidah	
1.	pH	--	7.19-7.44	8.09-8.19	8.13-8.19	--
2.	Biochemical Oxygen Demand (BOD_5)	mg/l	1434-1662	834-1422	819-1110	40
3.	Chemical Oxygen Demand (COD)	mg/l	9200-9600	7600-8800	8400-8800	--
4.	Total Solids (TS)	mg/l	38920-44560	38400-54410	41380-58890	--
5.	Total Suspended Solids (TSS)	mg/l	29650-30060	35360-52730	39540-56710	100
6.	Total Volatile Solids (TVS)	mg/l	19460-27980	31980-47570	32630-47360	--
7.	Volatile Suspended Solids (VSS)	mg/l	22240-22545	27220-39170	29580-41250	--
8.	Total Coliform (TC)	N/100ml	168000-444000	152000-230000	170000-231000	--
9.	Escherichia Coliform (E.Coli.)	N/100ml	117000-390000	121000-170000	110000-196000	1000 (Fecal Coliform)
10.	Sludge Volume Index (SVI)	ml/gm	26-33	19-27	23-25	--
11.	Iron (Fe)	mg/l	23-48	27-36	19-39	--
12.	Nitrate (NO_3)	mg/l	138-270	168-270	198-390	250
13.	Phosphate (PO_4)	mg/l	2184-2808	147-1527	105-171	35
14.	Electrical Conductivity (EC)	mS/cm	2.08-3.66	3.66-5.96	3.78-4.33	--
15.	Temperature	°C	20.1-24	29.7-30	29.6-30	30
16.	Total Alkalinity (as $CaCO_3$)	mg/l	4500-10500	9500-14000	9500-10500	--

4.6 Collection, emptying and transportation of fecal sludge

In the study areas, more than 85% of households practice unsafe FS emptying and conveyance. There are no safe emptying options available in the towns. For emptying septic tanks/pits, sweepers are largely used in all the areas. However, a combination of sweepers and mechanical cleaning is predominant in Kushtia. Kushtia Paurashava has been operating vacutug services for slightly longer than the other two towns. In all three towns, development partners and the Government of Bangladesh have provided logistical support to the local authorities for emptying, but due to lack of properly addressing the entire value chain the collected sludge is directly or indirectly being disposed into waterbodies. As a result, most households are assessed as unsafe emptying. Existing fecal sludge emptying and transportation practices have been investigated by field visit of each of the municipality under this study and with the discussion and interview of related persons of concerned department or section. The emptying and transportation practices have been observed physically.

4.6.1 Manual emptying

Traditionally, the sweepers are doing manual emptying in each of the cities. They do the job on-call basis. While emptying, they dig a ditch nearby the containment where land is available, otherwise they dispose it to the drains or waterbodies. Most of the people think that the sweepers are the only professionals who can empty the containment as they are not aware regarding the mechanical service. 81%, 34% and 98% of total emptying in Khulna, Kushtia and Jhenaidah have been found emptied by sweepers.

In Khulna, Kushtia and Jhenaidah, the population of sweeper community are 786, 912 and 441, respectively. There are 248 families in Khulna where 171 are engaged in manual emptying. In Kushtia only 22 and in Jhenaidah only 25 are engaged with manual emptying. Monthly income per family in Khulna, Kushtia and Jhenaidah are BDT 4287, 2716 and 2000, respectively. These numbers of sweepers are not enough to provide services in these city areas.

Table 4.10: Information of the sweeper of three cities

Particulars	Khulna	Kushtia	Jhenaidah
No. of Family	248	61	99
No. of manual emptier	171	22	25
Family Members	1068	270	441
Average income BDT/month	4287	2716	2000

Individual sweepers are playing an important role along with the municipality, especially in the suburbs where municipal services have not reached. In some cases people also took it upon themselves to clean.

Figure 4.27: Manual emptiers and emptying manually

Sometimes, they use drum carrying with van. Khulna city has two types of emptying devices. One is called boggy (Like boggy of train). This is actually manual emptying. The sweepers empty the pit/septic tank with bucket and the tank of the boggy or trailer is filled-in. Then the boggies are carried with engine and dumped elsewhere. The capacity of one boggy is 300 liters only. The charge for one boggy is BDT.300.

Figure 4.28: Manual emptying using boggy of KCC

4.6.2 Mechanical emptying

Now mechanical device has been invented by which the emptying of septage or fecal sludge is done mechanically. Mainly, vacuum tankers or vacutugs are being used as mechanical device in these three cities.

Khulna City Corporation

Khulna is largely dependent on the services of individual sweepers even though Khulna City Corporation (KCC) provides service. There are two 4000 liters capacity vacutugs in Khulna City Corporation. One vacutug is old one and is not functioning. Another One is functioning. These are 4000 liters capacity which the tank is carried by a tractor. The Vacutug is large and needs wide road. One has to apply and then pay a bank fee and deposit to KCC to get vacutug service. The charge for one emptying is BDT2875 including VAT (15%).

Figure 4.29: Vacutug of Khulna City Corporation

There are three vacutugs of Community Development Committees (CDC) provided by a project of UNDP namely Urban Partnerships for Poverty Reduction Project (UPPR). The operator of these vacutugs are the Cluster CDCs based at ward no.03, 17 and 22, respectively. They are providing service in entire city. The capacity of each vacutug is 1000 litres ($1m^3$). These can have access the roads of width 5 ft. The service charge is BDT500-700/trip. They do service on-call basis and with quick.

Figure 4.30: Mechanical Device-Vacutug operated by CDC, Khulna

Kushtia Municipality

In Kushtia, the Paurashava bears the major responsibility of sludge management. Kushtia Municipality started vacutug-based desludging operation for septic-tanks/pit-latrines from 2004 with a 500 litre capacity small vacutug. The vacutug operation suited the need for the treatment facility established in 2013 and also improved environment and health safety connected to desludging. Now, the municipality has 4 vacutugs with capacity of 500, 1000, 2000, and 4000 litres. The municipality is now serving 3-4 emptying services a day. A significant number of households in Kushtia do the cleaning themselves.

Figure 4.31: Vacutug of Kushtia Municipality

Jhenaidah Municipality

The situation in Jhenaidah is somewhat alarming as the Paurashava has very little capacity in dealing with sludge. Almost all of the activities related to cleaning and transporting are done by individual sweepers. They have 700 Liter, 1000 Liter and 2000 Liter vacutug.

Figure 4.32: Vacutug of Jhenaidah Municipality

Khulna City Corporation has one vacutug of 4 m^3 which service charge is Tk.2875/containment irrespective of septic tank or pit and even size. Community Development committee has three vacutugs of 1 m^3 each which charge is Tk.700/m^3. Average demand per month in Khulna per vacutug is 5. In Kushtia, there are two vacutugs running. The charge for septic tank is Tk.1000/septic tank and Tk.300/pit In Jhenaidah, charge for one septic tank is Tk.1000 and tk.500 per trip. Market size (emptying) of Khulna: BDT 355,000,000/year (710000m3xtk.500/m3), Kushtia: BDT 52,000,000/year (104000x500) and Jhenaidah: BDT 29,000,000/year (58000x500). Community Development Committee (CDC) and manual cleaning in Khulna required less time compared to the city corporation. Two-thirds of Khulna respondents who had their pit/septic tank emptied waited more than a day to get KCC services while 85% of respondents in Khulna received service within 24 hours from CDC.

4.6.3 Semi-mechanical emptying

For emptying septic tanks/pits, sweepers (manual cleaners) are used frequently in all of the study areas. However, a combination of sweepers and mechanical cleaning is predominant in Kushtia. The mechanical emptying process can pump the liquid portion, but manual intervention is required to clean the harder surface at the bottom of the tank/pit. Even the house owner compels the sweeper to clean the tank/pit entirely; to do this the sweeper has to climb down into the containment. A very insignificant percentage of households in Khulna and Kushtia deploy mechanical cleaning.

Table 4.11: Manual vs mechanical emptying

Types of emptying	Khulna		Kushtia		Jhenaidah	
	Count	%	Count	%	Count	%
Manually/Sweepers	1521	81	181	34	259	98
Combination of Manual and mechanical	320	17	330	61	1	0
100% Mechanical	24	1	3	1	1	0
Self	22	1	24	5	4	2
Others	3	0	0	0	0	0

Table 4.122: Service providers for pit/septic tank emptying

Types of Emptying	Khulna		Kushtia		Jhenaidah	
	No.	%	No.	%	No.	%
Municipal	309	16.3	333	61.9	2	0.8
CBOs	27	1.4				
Sweepers	1526	80.7	180	33.5	259	97.7
Self	22	1.2	24	4.5	4	1.5

Table 4.133: Time of Service for pit/septic tank emptying

Service Provider	Khulna			Kushtia		
	Service provided within 24 hours	Service provided after 24 hours	Total	Service provided within 24 hours	Service provided after 24 hours	Total
City Corporation/ Paurashava	33%	67%	100%	47	53	100%
CBO/CDC	85%	15%	100%	Not Applicable		100%
Sweeper (manual cleaning)	84%	16%	100%	92	8	100%

In Kushtia 25% of households emptied their septic tank less than six months ago; this is a much higher percentage than is found in Khulna (22%) but lower than in Jhenaidah (31%). The survey also found that about 22% of households in Khulna, 33% in Kushtia and 11% in Jhenaidah had not emptied their pit/tank within the last three years. The practice of safe septic tank emptying and conveyance is almost absent in Khulna city. More than half of the total households, irrespective of wealth quintile, either use unsafe emptying or do not at all practice faecal sludge emptying. The number is even higher for the top two groups of the quintile. The number of people in the wealthy groups who do not have a sludge emptying option is half that of the former group who are comparatively poor.

4.7 Findings on treatment and disposal of fecal sludge

Two-thirds or more of the households in all three locations practice environmentally unsafe treatment and disposal. Most people, irrespective of wealth and social status, deploy unsafe or partially safe treatment techniques while some households practice safe treatment methods; the trend is positively correlated with household wealth. In Khulna, since there is no proper disposal sites most of the sludge is dumped at undesignated ones. In Kushtia, as the treatment plant is smaller and far from city, a part of fecal sludge are dumped in drain or undesignated places. In, Jhenaidah, there is a treatment plant, but there is no demand of emptying. So, the treatment plant is idle and cannot function at all.

4.7.1 FS treatment in Khulna city

At present, there is no treatment plant in Khulna. There is only two trench at Rajbandh excavated just two years ago. Most of the vacutugs don’t go there for long distance from the city. Before this trench, there was no designated place for disposal.

Figure 4.33: Trenching ground in Khulna City

A fecal sludge treatment plant (Constructed Wetland) is ongoing at Rajbandh-2 with the funding of Bill and Melinda Gates Foundation (BMGF). The implementing agency is SNV Netherlands

Development Organisation. One acre land has been allocated by Khulna City Corporation for construction of fecal sludge treatment plant (FTP). The location of the FTP of Khulna is located at 22°47’39” latitude and 89°29’32” longitude outside Khulna municipality 10 kilometers away from city center. Existing FTP area is presented in the municipal landfill site which closed to paddy filed. This area was being used for pilot scale sanitary landfill site, during the period of 2008 – 2009.

Figure 4.34: Construction of ongoing Constructed Wetland (CW) in Khulna

The configurations of the ongoing FTP are summarized below:

1) This area was used as the pilot-landfill site

2) The total available area is about 55x70x3 m.

3) Currently, there is a little change of soil covering level due to the settlement

4) Nearby U-trench is temporary used for FS disposal, filtration into ground is expected. The final cover by top soil is planned after this trench is full.

Design considerations for Khulna FTP are as follows:

Plant: water emergent plants are selected to use for CW. The species used in the wetland receiving FS is the species that can stand for the high pollution as high TDS. Moreover, the species should be available in Bangladesh. Heliconia, Cyperus and Canna are selected in this design for the first CW. While, the later CW treating percolate uses mixed plants as Heliconia, Canna, Padanus plam and Lotus.

Media: Media in FS- CW units are aggregated brick and sand. The 3”, 2” and 1” are laid from bottom to top direction. Then, sand is the top layer. For media in Percolate-CW , shredded plastic is added in strip. The shredded plastic is used due to the availability in Bangladesh. It is also cheaper than rock, aggregate brick, or sand. The benefit of shredded plastic is the higher surface area which increasing amount of bacteria more than other media.

CW Pond: Plastic lining (HDPE) is designed to use as lining material for all CW units. It is due to the flexible of plastic which can be settle if the land settle as the behavior of old landfill. Compacted soil embankment is also expected to hold the CW pond.

4.7.2 Decentralized Wastewater Treatment Systems (DEWATS)

People’s Panchtala is a colony consisting 8 (eight) buildings just beside Khalishpur Wonderland Children park, Khulna. It was constructed in 1982 as staff quarter of people’s jute mills limited. Each building is five storied. So, it is named as Peoples Panchtala colony. In some buildings, 30 families and in some 100 families are living there. Total 2663 peoples are living here. After shut down of the mill, the peoples of the quarters are unemployed. So, there conditions are deteriorated day by day.

The inhabitants of these buildings are to struggle in their daily life. There were latrines of four chambers in one corner of each floor. The latrines were unhealthy. Somewhere one or two chambers are out of order and somewhere one chamber is being used as kitchen. So, on average 90 peoples were to use one or two chambers daily. The outside of the latrines as well as buildings were too bad. The septic tanks were broken and the dirty were overflown. Due to no management of the drain, the wastes were thrown here and there. The huge dumped of the wastes were seen to the entrance of the colony. Not only outside, it was also at the staircases. The total conditions were too unhygienic to live here for the human beings. The children, aged peoples, adolescents were suffering from various kind of diseases. As consequences, the people were suffering physically, economically and socially.

Nabolok, one NGO under assistance of WaterAid Bangladesh came forward to improve the situations. They constructed four DEWATS for four buildings. The sitiuations has changed tremendously. 80 Latrines are made hygienic for 680 peoples of 165 families. The environment has been improved. The water quality of the DEWATS of Khulna are more or less better. BOD 510-900 mg/L in inlet but 33 in outlet (Source: Nabolok, 2016). The performance of DEWATS is good. The peoples of this colony are happy now.

4.7.3 FS treatment in Kushtia municipality

Kushtia municipality has a fecal sludge treatment plant. Responding to the challenge of Kushtia's growing faecal sludge management (FSM), an initiative has been taken by Waste Concern, a waste-centred consulting organization, in partnership with the Kushtia Municipality. With the support from the Institute for Global Environmental Strategies (IGES) and United Nations Centre for Regional Development (UNCRD) and in partnership with the Department of Environment (DoE) under Ministry of Environment & Forest, Bangladesh, Waste Concern and Kushtia Municipality jointly established a pilot composting plant at Baradi in 2008. The municipality started co-composting as a part of Faecal Sludge Management (FSM) since January 2013. FTP of Kushtia is located at 23^{o}54'38" latitude and 89^{o}7'20"longitude in Ward no. 1.

The treatment is a drying bed with co-composting plant. There are two units of drying bed for solids deposition. Then liquid is passing through filtering media to a collection tank. The liquid is then pumped to coco-pit filter. After filtering the liquid is discharged to a reserved pond/ditch.

From the observation, configurations of the existing FTP are summarized below:

1) There are 2 units of sludge drying bed (2 beds x 6.05 x 10.2x 0.8 m as W x L x H).

2) The 2 inlet chambers are 2 chambers x 2.15 x 6.05 x 0.5 m.

3) There are filter media in treatment beds. The perforated tubes were also installed at the bottom of tank and connected to effluent tank.

4) Hydraulic loading rate is 0.3 m^3/m^2.

5) Timing to get dried sludge in each batch is depended on weather. It is may be more than 10 days or more than 20 days during rainy season.

6) Maximum feed is 70 trips per bed (700L/trip)

7) After sludge dried, it will be removed by manually.

Figure 4.35: Drying Bed and Co-compost Plant of Kushtia Municipality

4.7.4 FS treatment in Jhenaidah municipality

Jhenaidah has virtually no services for safe sludge management, not even from the Paurashava. But with support from DPHE, a treatment plant was been constructed in 2012. The plant is located in the west side of city at 23º32'58" latitude and 89º7'17" longitude, which is outside of Jhenaidah Pourashava.

The existing treatment plant is constructed wetland (CW) system which can operate at 90 m^3/week based on loading of 0.3 m^3/day with 2-3 days HRT, and resting period of 2-3 days before receiving new loads. The calculated capacity of this plant is about 4,700 m3/year.

Figure 4.36: Existing Treatment Plant of Jhenaidah Municipality

From field observation, details of existing FTP are as follows:

1) Two units of CW, each has a dimension of 9 x16 m. as shown in Fig. 4.43.

2) The wall is 2 m height.

3) Valve is used for controlling liquid in CW bed

4) Effluent is further discharged into canal

5) Plant in CW is now not in a good shape (see in Fig.4.43)

6) Air pipe is connected to the drained pipe

4.8 Reuse of Treated Sludge

There is a very high variance in knowledge and practice of resource recovery and use. About 79% of households in Kushtia consider faecal sludge is a resource and reusable. This knowledge has come from the establishment of a co-composting plant by the local authority. The ratio is far lower in Khulna (52%) and Jhenaidah (28%). A very insignificant number of households used resources recovered from faecal sludge, primarily for agriculture. There are also some cases where households are using recovered faecal sludge as fish feed and as an input to biogas plants. Only 114 cases in Khulna and Kushtia reported that they think faecal sludge as a resource. In Jhenaidah there is no such case. Households that used FS mentioned that it was used for fish feed, poultry feed, the kitchen garden, agriculture and producing biogas. Among those uses 'agriculture' was mentioned by most respondents.

In Khulna, there is a biogas plant at Khalishpur Bihari colony using the community toilets. In Kushtia, co-compost is being produced and two action researches are going on use of FS in agriculture with Bangladesh Agricultural Research Institute (BARI) and in aquaculture with department of Fisheries and Marine Resource Technology (FMRT, Khulna University). In Jheanidah, there is no example of reuse of fecal sludge.

4.8.1 Co-composting Process in Kushtia Municipality

Kushtia municipality started co-composting as a part of Faecal Sludge Management (FSM) since January 2013. Faecal sludge is directly collected from the septic tanks or pit latrines using vacutugs (i.e. vacuum trucks) and discharged at the drying-bed of the treatment facility. Here, the liquid part is filtered through coco peat filtration unit and released into the environment which is safe. The dry sludge is co-composted with municipal organic waste to use as soil conditioner. This treatment plant has the monthly capacity of treating 50,000-60,000 litre of sludge, much lower quantity compated to the actual amount of sludge generated. Demand creation and marketing of co-compost generated in the treatment plant is crucial to make the system sustainable. Responding to this need, SNV Netherlands Development Organisation commissioned two researches: one with Bangladesh Agricultural Research Institute (BARI) and the other with Fisheries and Marine Resources Technology Discipline (FMRTD) of Khulna

University to promote FS co-compost with scientific evidence. Here, the co-compost generated in Kushtia treatment plant has been used as research material.

Figure 4.37: Steps in FS co-composting and distribution in Kushtia Municipality

Figure 4.38: FS co-compost using at Agriculture (Research and Demonstration by BARI)

Figure 4.39: FS co-compost using at aquaculture (Research and Demonstration by FMRT, KU)

4.9 Shit-Flow Diagram (SFD)

Shit flow Diagram of Khulna City

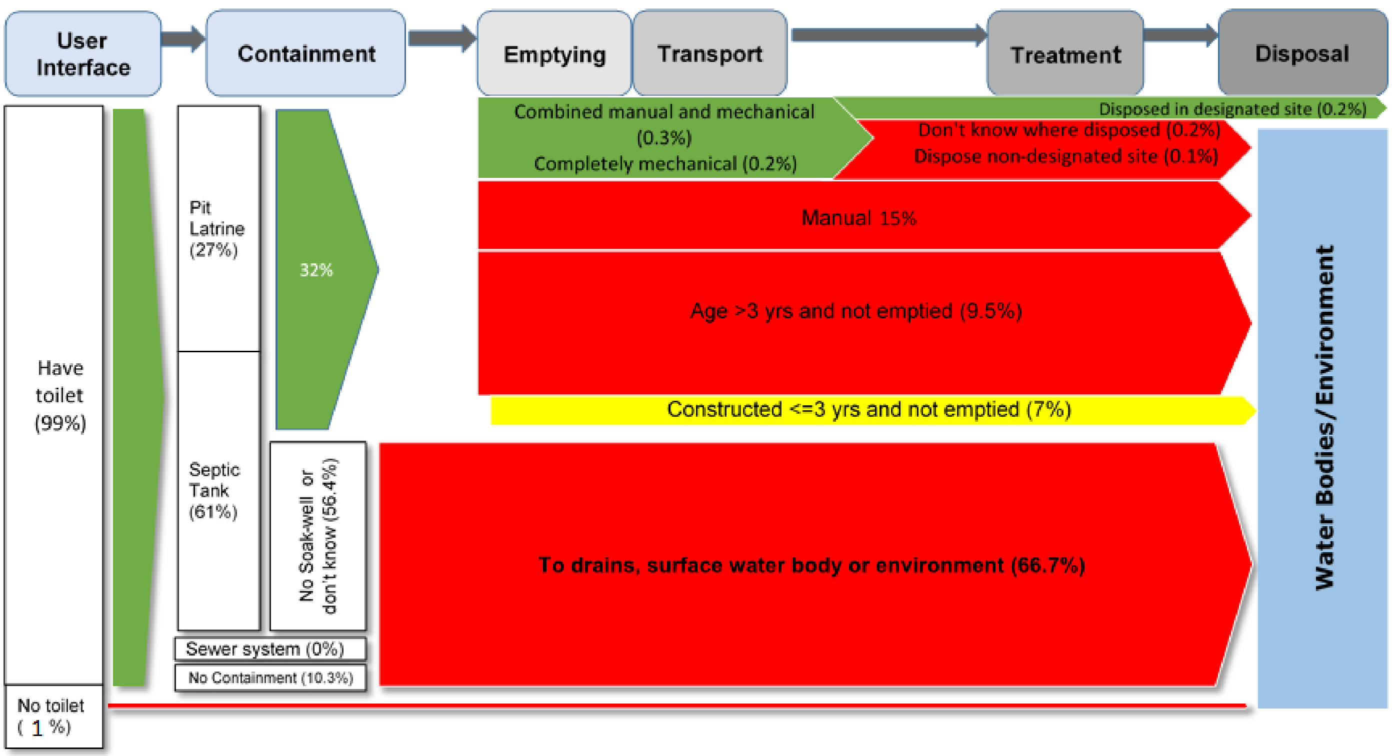


Figure 4.40: Shit flow Diagram of Khulna City (Source: Baseline Survey of SNV and KU, 2014)

In Khulna 99% of households have toilets, so in terms of user interface, this is good and hence the color is green. On the other hand, 1% still don't have toilets and directly goes to the water bodies or environment. So, the color is red. In containment, there are 27% are pit latrine, means enclosed, so the color is green. There are 61% septic tank of which 56.4% have no soak well (and or don't know) which are in red zones and the rest (32%) have containment and or soak well and lies in green zone. There is no sewer in Khulna city. Another 10.3% have no containment. So, both these are marked as red. In emptying and transportation, 0.2% is completely mechanical and 0.3% are combined manual and mechanical emptying. As these are comparatively safer, the portion is marked as green. 15% manual emptying and 9.5% septic tank and or pit which are constructed more than 3 years and are not emptied marked as red. On the other hand 7% septic tank and or pit which are constructed less than 3 years and are not emptied marked as yellow, compared as better than previous one. In treatment and or disposal, only 0.2% are disposed in designated places marked as green. The rest are in red portion.

Shit flow Diagram of Kushtia municipality

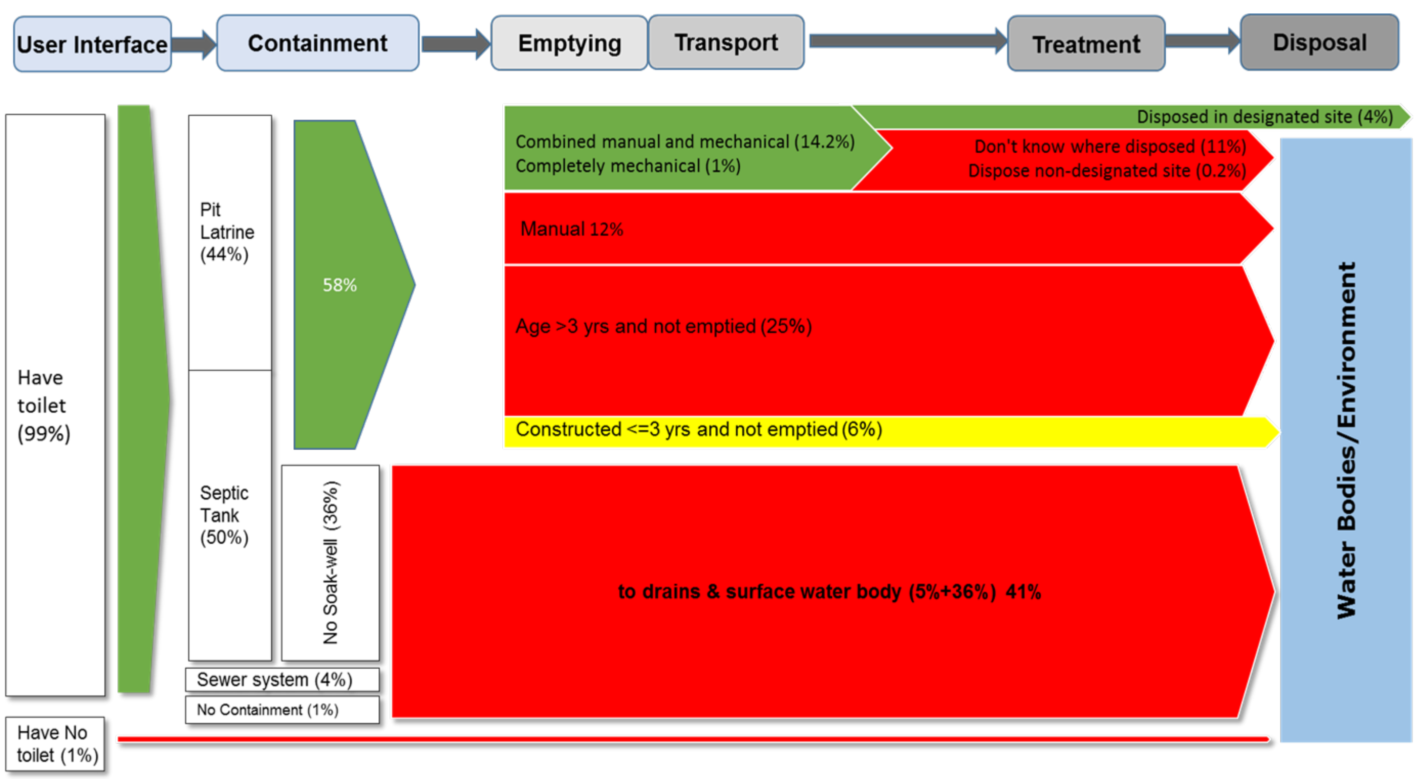


Figure 4.41: Shit flow Diagram of Kushtia municipality (Source: Baseline Survey of SNV and KU, 2014)

In Kushtia, 99% of households have toilets, so in terms of user interface, this is good and hence the color is green. On the other hand, 1% still have no toilets and directly goes to the water bodies or environment. So, the color is red. In containment, there are 44% are pit latrine, means enclosed, so the color is green. There are 50% septic tank of which 36% have no soak well which are in red zones and the rest have soak well and lies in green zone. There are 4% sewer in Kushtia city in ward no.6 but there is no treatment plant for this and ultimately goes to the river and another 1% have no containment. So, both these are marked as red. In emptying and transportation, 1% is completely mechanical and 14.2% are combined manual and mechanical emptying. As these are comparatively safer, the portion is marked as green. 12% manual emptying and 25% septic tank and or pit which are constructed more than 3 years and are not emptied marked as red. On the other hand 6% septic tank and or pit which are constructed less than 3 years and are not emptied marked as yellow, compared as better than previous one. In treatment and or disposal, only 4% are either treated and or disposed in designated places marked as green. The rest are in red portion.

Shit flow Diagram of Jhenaidah Municipality

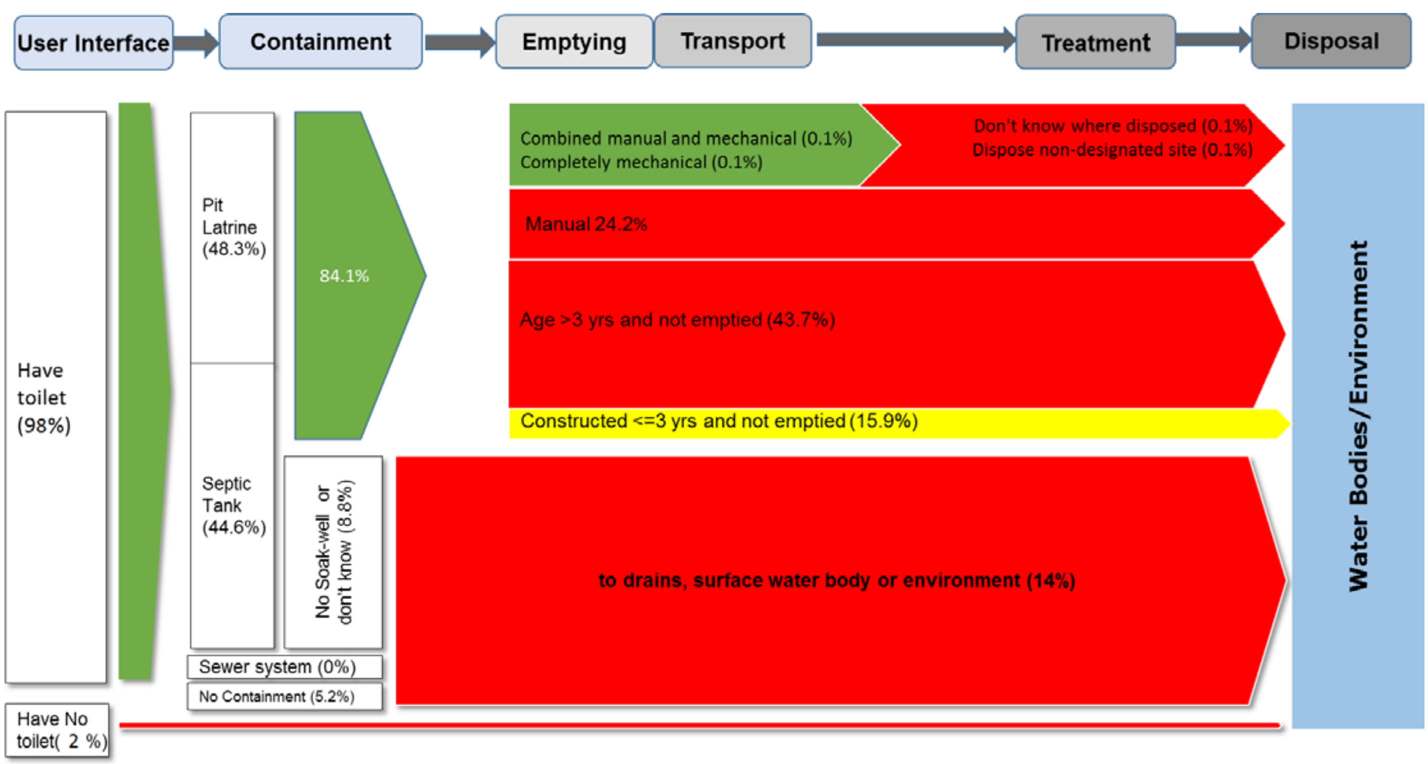


Figure 4.42: Shit flow Diagram of Jhenaidah Municipality (Source: Baseline Survey of SNV and KU, 2014)

In Jhenaidah, 98% of households have toilets, so in terms of user interface, this is good and hence the color is green. On the other hand, 2% still have no toilets and directly goes to the water bodies or environment. So, the color is red. In containment, there are 48.3% are pit latrine, means enclosed, so the color is green. There are 44.6% septic tank of which 8.8% have no soak well (and or don't know) which are in red zones and the rest (84.1%) have containment and or soak well and lies in green zone. There is no sewer in Jhenaidah. Another 5.2% have no containment. So, both these are marked as red. In emptying and transportation, 0.1% is completely mechanical and 0.1% are combined manual and mechanical emptying. As these are comparatively safer, the portion is marked as green. 24.2% manual emptying and 43.7% septic tank and or pit which are constructed more than 3 years and are not emptied marked as red. On the other hand 15.9% septic tank and or pit which are constructed less than 3 years and are not emptied marked as yellow, compared as better than previous one. In treatment and or disposal, nothing is disposed in designated places nor treated. So, all the emptied fecal sludge are in red portion.

4.10 Health and Hygiene issues

Health and hygiene issues are prevailing in every components of the value chain of Fecal Sludge Management. Residents of the three cities have used and maintained toilets in a hygienic way (Khulna 36.47%, Kushtia 42.08% and Jhenaidah 28.70%). Safety of emptying and collection was classified based on where the sludge is being conveyed after emptying and the type of containment being used. Unsafe emptying or conveyance is categorized at the lower level, where the sludge is directly discharged to the environment; or pits have not been emptied within the last three years; or emptying is done with someone entering the containment without personal protective equipment (PPE).

Figure 4.43: Emptying and processing without using any PPE

The peoples engaged with emptying both manual and mechanical, disposal, preparation of co-compost and reuse in field are in risk of health. An Occupational Health and Safety manual for the emptiers and an Occupational Health and Safety Guidelines for the municipality have been developed (Source: FSM Program-KCC, 2016).

4.11 Conclusions

Each component of value chain of fecal sludge management has been thoroughly investigated. Different types of toilets have been found in the study area. In Khulna 99% of households have toilets, only 1.3% have no toilets. But 66.09 % of the toilets are improved toilets, the rest 33.91% are unimproved. In containment, there are 27% are pit latrine and 61% septic tank of which 56.4% have no soak well and the rest 32% have containment and or soak well. There is no sewer in Khulna city. Another 10.3% have no containment. In emptying and transportation, 0.2% is completely mechanical and 0.3% are combined manual and mechanical emptying. 15% manual emptying and 9.5% septic tank and or pit are emptied more than 3 years. On the other hand 7% septic tank and or pit are emptied in less than 3 years. Khulna City Corporation has two vacutugs (4000 Liters) of which one is not functioning. In private sector, Community Development Committee (CDC) has three vacutugs of 1000 liter each. Though the demand and use of vacutugs are very less in this city, the service of CDCs are better than City Corporation. In treatment and or disposal, only 0.2% are disposed in designated places although there is no treatment plant in this city.

In Kushtia, 99% of households have toilets and 1% still have no toilets and directly goes to the water bodies or environment. But 63.51% of the toilets are improved toilets, the rest 36.49% are unimproved. In containment, there are 44% are pit latrine and are enclosed. There are 50% septic tank of which 36% have no soak well and the rest have soak well. There are 4% sewer in Kushtia city in ward no.6 but there is no treatment plant for this and ultimately goes to the river and another 1% have no containment. In emptying and transportation, 1% is completely mechanical and 14.2% are combined manual and mechanical emptying. 12% manual emptying and 25% septic tank and or pit are emptied more than 3 years. On the other hand 6% septic tank and or pit are emptied constructed less than 3 years. The municipality has started vacutug services since ten years. In this municipality, there is a drying bed with coco-peat filter. But only 4% are either treated and or disposed in treatment plant. The municipality is producing co-compost, but use of this soil conditioner is very less.

In Jhenaidah, 98.1% of households have toilets, and 1.9% still have no toilets and directly goes to the water bodies or environment. But 43% of the toilets are improved toilets, most (57%) of the toilets are unimproved. In containment, there are 48.3% are pit latrine and are enclosed. There are 44.6% septic tank of which 8.8% have no soak well (and or don't know) and the rest (84.1%) have containment and or soak well. There is no sewer in Jhenaidah. Another 5.2% have no containment. In emptying and transportation, 0.1% is completely mechanical and 0.1% are combined manual and mechanical emptying. 24.2% manual emptying and 43.7% septic tank and or pit are emptied which are constructed more than 3 years. On the other hand 15.9% septic tank and or pit are emptied which constructed less than 3 years. Department of Public Health Engineering (DPHE) has constructed a treatment plant and handed over to the municipality with vacutugs. But due to lack of experience, the use of vacutug and treatment plant is very less.

In all these municipalities, manual emptying are being predominantly used. There are lack of use of personal protective equipment (PPE) in both for manual and mechanical and health-safety issues are neglected.

CHAPTER V
IDENTIFIED PROBLEMS OF FSM IN THE STUDY AREA AND PROPOSALS FOR IMPROVEMENT

5.1 General

Fecal sludge management (FSM) services in three cities/towns: Khulna, Kushtia and Jhenaidah municipalities are almost new issue or sector. Based on the entire value chain of FSM, the problems have been identified and hence some improvement proposals have been recommended.

5.2 Identified Problems of FSM in the Study Area

Toilet

The unimproved toilets in Khulna Kushtia and Jhenaidah were found to be 34%, 37% and 57%, respectively. The Major causes of unimprovement were due to lack of water seal and non-functioning Y-junction. The twin pit latrines without a 'Y-junction' are found in 38% and 55% of households in Khulna and Kushtia, respectively. There are a considerable number of toilets connected to one or more than two pits that are merely containments and do not comply with the principles of twin pit latrines. In Khulna 45% of households living in slums located on private land are using a shared toilet while in Kushtia and Jhenaidah the proportion is 30% and 12% respectively. These are also categorised as unimproved as per definition in the Joint Monitoring Programme (JMP of WHO/Unicef, 2015). About one-third of the toilets are functional, clean (no faecal smears, walls and doors are in place, no cleansing materials are on the floor and water is available) in all three cities. In Khulna 18% of households are using a toilet with functionality problems; in Kushtia this number is 6% and in Jhenaidah 19%. Common issues are no water seal, blockage in the water seal or that unimproved toilets are in use. Some are using shared toilets. Y-junctions of twin-pit toilet are not functional in many cases.

Containment:

Septic tanks are not constructed as per design of Bangladesh National Building Code (BNBC). There is no inspection mechanism of septic tank construction. In Khulna and Kushtia, most of the toilets with septic tank has no soak well and these are connected with drain. People's perception is that soak well does not work due to high water table. Masons are not trained and skilled enough for construction of septic tank as per requirement of design. In Khulna, Kushtia and Jhenaidah 84.0%, 68.3% and 15.7%, respectively of septic tanks have no soak well. The main cause is due to high water table and ignorant of the matter.

Figure 5.1: High level of underground water table

Emptying and Transport Services

Manual emptying and transport

Traditionally, the sweepers are doing manual emptying in each of the cities. 81%, 34% and 98% of total emptying in Khulna, Kushtia and Jhenaidah have been found emptied by sweepers. They do the job on-call basis. While emptying, they dig a ditch nearby the containment where land is available, otherwise they dispose it to the drains or waterbodies. Most of the people think that the sweepers are the only professionals who can empty the containment as they are not aware regarding the mechanical service. Almost all households in the three cities practise unsafe emptying and conveyance irrespective of wealth quintile.

Mechanical emptying and transport

In Khulna, Kushtia and Jhenaidah completely mechanical emptying is only 1 % or less. Even though Vacutug service was introduced a few years ago in Khulna and Kushtia, it is not yet functioning properly. Since there are no proper disposal sites in Khulna, most of the sludge is dumped at undesignated ones. There is no consistency in emptying frequency among households as most containments are substandard and connected to waterbodies. Vacutug does not have access in narrow alley. It also cannot extract the hard solid part of the bottom of septic tank due to not emptying since many years. So, after extracting liquid part from the septic tank, the emptier go down of the septic tank and clean the solids manually. Most of the time the vacutug remain idle and heavily underutilized. As a result they incur losses. The vacutugs are not registered in any of the cities of study areas. The vacutugs are moving illegally in the cities. The licensing authority Bangladesh Road Transport Authority (BRTA) has not any provision for giving license for the vacutug as it is not categorized in their rules.

Fecal Sludge Treatment

In Khulna, there is no treatment plant or designated site for disposal but two trenches at Rajbandh. But due to far from city and lack of enforcement, all sludge are not dumped there rather than dumped hither and thither. Even though Kushtia and Jhenaidah have treatment plants the services have not been established as envisioned; having an infrastructure without any demand-side activities does not ensure proper FSM services. In Khulna, there are some DEWATS with using large space although crisis of land in urban areas.

From the field observation the limitations of the plant of Kushtia are:

1) The sequence of feeding is based on drying period

2) The different of bottom level of inlet chamber and sludge drying bed is 0.45 m.

3) Loading operation is running bed to bed, likely after fully in one bed, then the next one.

4) Manually removed of dried sludge is expected when the sludge is dried.

From the field observation the limitations of the plant of Jhenaidah are:

1) Distribution of FS was not equally over surface of treatment unit.

2) Current plant in CW does not have a good rooting system.

3) There was no provision for percolate treatment.

Final Disposal or Reuse

In Khulna, there is no treatment plant but having a trenching ground, but all the fecal sludge collected from the containment are not disposed to the designated place. There is no use of fecal sludge in Khulna except a small biogas plant at Bihari colony. In Kushtia, the treatment plant is very small. So, all the sludges are not dumped there rather than hither and thither. Kushtia Municipality is producing co-compost, but they didn't get license from the government due to not meeting the standard of quality. So, the use of co-compost is limited. In Jhenaidah, the treatment plant has only one unit for treatment for fecal sludge but not for percolate one.

Health and Safety

Health and safety issues are neglected. No personal protective equipment (PPE) is used in any towns of the study area. Sometimes, they wear only to show the visitors. Sweepers or operators of vacutug are not used to and don't feel comfort of using PPEs.

5.3 Proposals for Improvement of FSM in the Study Area

Every steps of the value chain of Fecal Sludge Management (FSM) have thoroughly investigated in three towns of the study areas. Many problems have been identified in respect of toilets, emptying and transportation, treatment and disposal or reuse and also some general issues on management. Some proposals have been suggested city wise and some are in general for all the cities of study areas. The Proposals for Improvement of FSM in the Study Area described as below:

5.3.1 Khulna City Corporation

Improvement of Toilet

In Khulna, only placement of water seal and Y-junction can make the toilets improved. Proper maintenance of the toilets can keep the toilets hygienic and improved. It will improve the rest 34% unimproved of Khulna city and contribute to 52% urban sanitation of Bangladesh (WHO/JMP, 2015).

Up-gradation of Containment

In the study area, there are septic tank and pit latrines. Septic tanks are not constructed as per proper design. BNBC to be followed. Soak well is needed. But due to limited space, the people do not want to make soak well. Also due to high water table, it does not work. So, up-gradation of septic tank is necessary. A research on upgradation of septic tank is highly desirable.
84% of Septic tank of Khulna are connected with drain. So, disconnection of these huge number of septic tank is impossible. But new connection to be stopped. Enforcement is required to do this work. Community septic tank can be done where space is available.

Small Bore Sewers (SBS): Small Bore Sewerage might be an option for densely populated low-income communities. Household connections may be 6 - 12” in diameter, and septic tanks designed similar to Anaerobic Baffle Reactors (ABRs). SBS are designed to collect and transport only the liquid portion of wastewater via gravity for off-site treatment. SBS typically transport effluent from interceptor or septic tanks, which contains fewer solids thus reducing water requirements and flow velocities. SBS may be designed with both open channel flow or with some sections below the hydraulic gradient line. Minimum pipe diameter is 100 mm, but strict sewer gradients may not be necessary due to the lack of solids. The minimum wastewater velocity is in the range of 0.3 to 0.6 metres per second. Regular desludging of the septic tanks is required by households to ensure solids do not flow into the SBS. If these is maintained, the risk of clogging is low but some period maintenance (flushing of sewers) would be undertaken on an annual basis.

Table 5.1: The advantages and disadvantages of SBS

Advantages	Disadvantages
- Reduced water requirements - Relatively low-cost vs conventional sewers - Can be constructed with local materials - Simple to maintain - No energy requirements	- Regular cleaning of septic tanks - Well planned maintenance system required - Solids entering sewers create blockages - All block resident’s acceptance necessary

Figure 5.2: Small Bore Sewer (Source: https://www.google.com/small bore sewerage)

Most of the house owners are dependent on the masons for the construction of septic tank. The masons are also not trained and they don’t have sufficient knowledge of the functions of septic tank. Trained masons/inspectors of on-site systems, environmental consequences and people’s health is very essential. So, the masons need training.

Khulna Development Authority (KDA) in case of Khulna City is the approval authority of building. Submission of the details design or drawing of septic tank is not mandatory. KDA can orient the designers in this regard. They have inspectors for inspection of building. They are mostly interested on building construction, not for the septic tank. Building code must be followed and inter-cooperation in between relevant institutions (KCC, KDA, KWASA, NHS, etc.) is necessary and joint efforts are essential to sustain safe sanitation systems.

Training and registration of the Manual Emptiers

The main profession of sweepers are cleaning the toilet, emptying the containment. They maintain their family with this income. So, they cannot be stopped. But they should be trained regarding use of protective gears and to be health concerned. Manual emptiers can be registered by City Corporations or Pourashava so that only they can provide the service.

Small emptying device

Khulna is a big city. There are many narrow roads where no vacutug can enter to the septic tank. Small devices gulper, electric, diesel and diaphragm pumps, etc. can be tested and used (BRAC study report, 2015).

Table 5.2 shows some of the key characteristics of the pumps used in this study. The results from the testing of the different pumps suggest that the use of pumps in rural conditions is not entirely straightforward. The gulper has low capital and operational costs and is effective for cleaning pits containing sludge with a wide range of moisture content (i.e., from liquid to dry FS); however its bulky size and weight is likely to damage the superstructure and slab of the latrine. It also requires special transportation, and its operation is complicated in comparison with other tested options.

The diaphragm pump is light in weight and easy to use. It has low energy and maintenance costs, requires few workers and it is unlikely to cause damage to the latrine. The diaphragm pump was able to empty a pit latrine 30% faster than manual emptying. However, it has high capital costs, with a pump costing BDT 30,000.

The diesel pump significantly reduces the emptying time in comparison with the other tested options. However, it has high capital and operational costs, and is heavy to transport and use.

The electric pump has low capital costs, is light weight and easy to use. However, with the erratic supply of electricity in rural areas, its use in pit emptying practice is likely to be limited.

Table 5.2 Emptying devices

Parameter	Gulper	Diaphragm	Diesel	Electric
Capital / Purchasing costs	Low	High	Med	Low
Energy costs (per pit)	Low	Low	High	Med
Maintenance costs (annual)	Low	Low	High	Med
Ease of use in rural areas	Difficult	Easy	Difficult	Easy
Ease of handling	Difficult	Easy	Difficult	Difficult
Labour requirement (per pit)	Medium	Low	Medium	Medium
Need for transportation (per pump)	Yes	No	Yes	No
Ideal pit depth (foot)	3-5	3-10	10-15	3-10
Pit emptying charges (BDT per pit)	500-1500	500-1500	1500-2000	1500-2000
Health and Environmental risks	High	Low	Med	Med
Probability of damaging latrine	High	Low	Med	Low
Preparation time (minutes)	15-20	10-15	20-30	15-20
Pit emptying time (minutes)	20-30	15-20	5-10	5-10

Given these constraints, the diaphragm pump emerged as the most feasible option for reducing contact with sludge while emptying rural pits. Debriefing conversations with sweepers in Bhaluka and Fultola revealed that they were unlikely to purchase the pump of their own accord due to its high capital costs. Therefore, the government/municipality would need to provide a subsidy/incentives to facilitate the purchase of these pumps. However, this is a one-time subsidy, and not a recurring one. The cost of the pump will likely be recovered over the lifetime of the pump.

Figure 5.3: Small emptying devices (Source: BRAC report, 2015)

Current vacutugs cannot extract the solid part from the bottom of septic tank which are too old. So, power excrevator/auger type device can be introduced.

Figure 5.4: Power Excrevator/Augur (Source: North Carolina State University, 2015)

Secondary Transfer Station

There are two systems for emptying containment, i.e. pit or septic tank of a toilet. One is traditional systems where the sweepers do the emptying manually. The other system is mechanically. Vacutug is one of the mechanical device for emptying the containment of toilet.

In Khulna, there are two big vacutugs belong to Khulna City Corporation. These are wide, so cannot go to the narrow road of the city. Beside these, there are three small vacutugs belong to Community Development Committee (CDC) provided by one project of UNDP namely Urban Partnerships for Poverty Reduction (UPPR). The capacity of these small vacutugs are 1000 liters. These vehicles can go most of the road of the city.

The dumping or disposal site of Khulna City is about 12 Kilometres from City Corporation and more distance from the end of the city. It consumes more fuel and more time to run from the containment to the disposal point. If there is intermediary secondary transfer station (STS), the small vacutug can dispose into the big STS. After taking many trips from the small one, the STS can go to the disposal point. Thus the fuel cost and time can be minimized and the operator can provide service efficiently and effectively with a profitable business.

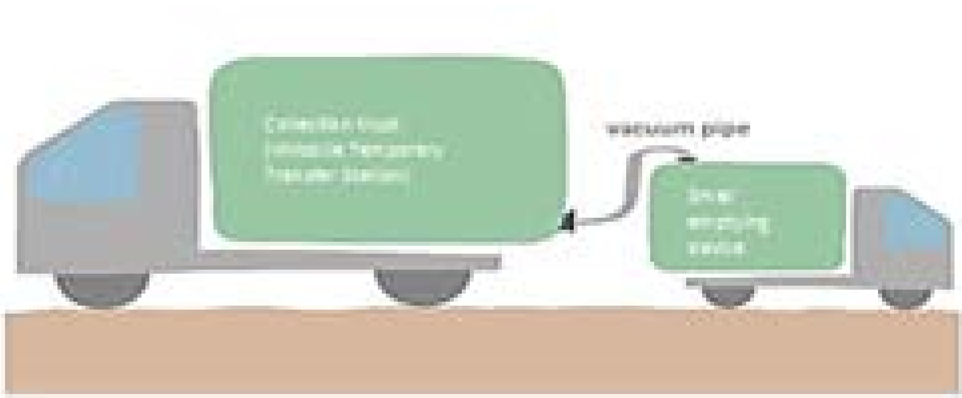


Figure 5.5: Mobile Secondary Transfer Station (Source: Dgroup Discussion of SNV, 2015)

Treatment Process

Treatment technology should be simple, easier. As the issue is new in Bangladesh. City authority is not too much interested on managing the treatment plant. They don't have manpower in their current organogram. So, the treatment plant should be with very less maintenance. Appropriate technology for emptying and treatment is required. DEWATS can be used for community level but design should be modified with using of less space as there is space crisis in urban area.

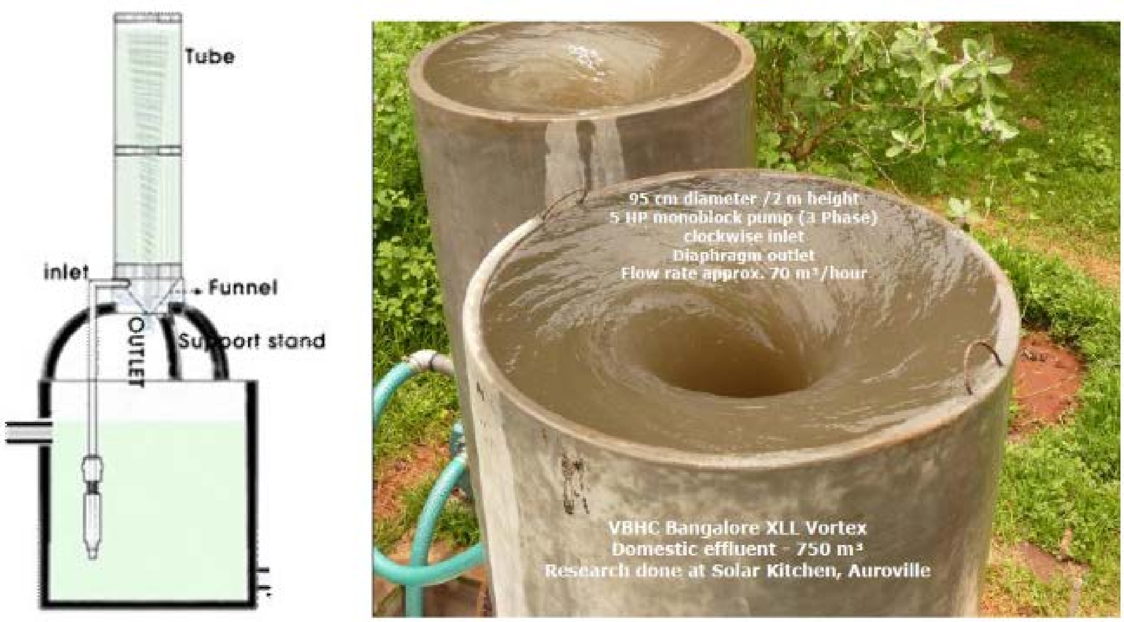


Figure 5.6: Vortex System with DEWATS (Source: CDD, 2016)

Call center to streamline the whole process

A 'Call Center' can be established to connect faecal sludge emptying operators to households in need on mechanical emptying. Mobile phone is now available to everywhere. In Bangladesh, now mobile phone is in every household. More than 130 million people, out of Bangladesh's population of 160 million, use mobile phones while around 50 million people access internet (bdnews, 2015) .The objective of the call center is to make available to the sanitation players (i.e. emptying operators, regulators and households) a tool for improvement and optimization services for a Multi-Channel Service Platform (MCSP). The call center is looking to reduce the costs of emptying through tenders. The Prospects of call center are Continuous improvements in technical robustness of Call Center, Tracking Call Centre Operations, Business model and trade policy, Campaign of mass communication, tracking faecal sludge treatment plant (privatization) and Geo-referencing of trucks. As new sanitation technologies grow and scale in developing countries, we believe mobile network operators will also get benefits from working with this Call Centre. Linking mobile services to sanitation services that are innovative and aspirational can increase customer uptake through branding and marketing. (Market Structuring of Fecal Sludge Management Program, ONAS-Dakar).

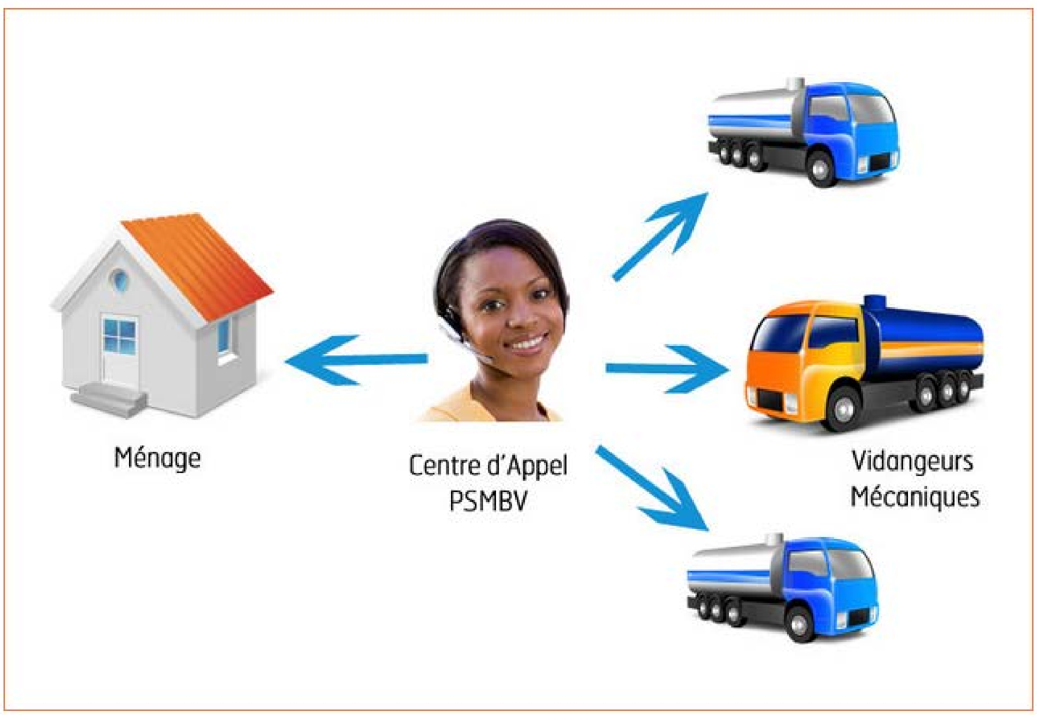


Figure 5.7: Call Center (Source: Market Structuring of FSM Program, ONAS-Dakar, 2015)

5.3.1 Kushtia Municipality:

Improvement of Toilet

In Kushtia, placement of water seal and Y-junction can make the toilets improved. Proper maintenance of the toilets can keep the toilets hygienic and improved. It will improve 55% unimproved toilets of Kushtia and contribute to improve 52% unimproved urban sanitation (WHO/JMP, 2015)

Up-gradation of Containment

In the study area, there are septic tank and pit latrines. Septic tanks are not constructed as per proper design. BNBC to be followed. Soak well is needed. But due to limited space, the people do not want to make soak well. Also due to high water table, it does not work. So, up-gradation of septic tank is necessary.

Most of the house owners are dependent on the masons for the construction of septic tank. The masons are also not trained and they don’t have sufficient knowledge of the functions of septic tank. So, the masons to be trained.

68% of Septic tank of Kushtia are connected with drain. So, disconnection of these huge number of septic tank is impossible. But new connection to be stopped. Enforcement is required to do this work. Community septic tank can be done where space is available.

Training to the Manual Emptiers

The main profession of sweepers are cleaning the toilet, emptying the containment. They maintain their family with this income. So, they cannot be stopped. But they should be trained regarding use of protective gears and to be health concerned. Manual emptiers can be registered by the Pourashava so that only they can provide the service.

Small mechanical device

In narrow road, no vacutug can enter to the septic tank. Small device like gulper can be used. Current vacutugs cannot extract the solid part from the bottom of septic tank which are too old. So, power excravator/auger type device can be introduced.

FSM as Market Based Solution

There are lots of scope of business in fecal sludge management. The business can start from constructing toilets. The containment up-gradation is now an issue. The potentiality of huge business in in collection, emptying and collection of fecal sludge from the containment. The treatment and resource recovery has also a kind of business. Bangladesh is an agricultural country. It needs huge quantity of fertilizer. FS can be a potential source of this.

Testing of different service modalities and pricing structures to make the desludging services profitable and also equitable; and finally, outsourcing of different FSM services and promote market-based solution across the sanitation and faecal sludge value chain. Public Private Partnerships (PPP) can run this business.

Additional Treatment Plant

As the existing treatment plant is very small, a big one is necessary to meet the demand of the municipality. In Kushtia municipality, estimation of fecal sludge generation were 1,04,581 1,09,527 m^3/year. But the capacity of the present treatment plant is only 2% of the total. So, a big treatment plant with co-compost plant will mitigate the problem and the municipality will be beneficial.

5.3.2 Jhenaidah Municipality

Toilet upgrading

In Jhenaidah, only placement of water seal can make the toilets improved. Proper maintenance of the toilets can keep the toilets hygienic and improved. It will contribute to improve the rest 52% unimproved urban sanitation (WHO/JMP, 2015).

Training to the Manual Emptiers

The main profession of sweepers are cleaning the toilet, emptying the containment. They maintain their family with this income. So, they cannot be stopped. But they should be trained regarding use of protective gears and to be health concerned. Manual emptiers can be registered by Pourashava so that only they can provide the service.

Small mechanical device

In narrow road, no vacutug can enter to the septic tank. Small device like gulper can be used. Current vacutugs cannot extract the solid part from the bottom of septic tank which are too old. So, power excrevator/auger type device can be introduced.

Treatment Process

Unit for percolate treatment facility is needed. Treatment technology should be simple, easier. As the issue is new in Bangladesh. City authority is not too much interested on managing the treatment plant. They don't have manpower in their current organogram. So, the treatment plant should be with very less maintenance. Existing treatment plant to be upgraded as there is no unit for leachate treatment.

5.3.3 Way Forward for Overall Improvement in FSM

Social Awareness

There is taboo regarding fecal sludge. This is just for lack of knowledge and awareness. So, proper steps can be taken for raising awareness to the individual person, households, community. This widespread issue points to a need for behavior change interventions along with the introduction of simple and usable technologies. While behavior change interventions are not the bright and shiny inventions displayed in tech conferences, they are the key to ensuring the success of new technologies introduced in the sanitation chain. It is important to get consumer's perspectives on existing sanitation and FSM systems, and include behavior change. The following actors play a role in the management of faecal sludge:

Stakeholders in faecal sludge management and what are their roles and challenges. Key stakeholders in FSM are the households, the community, governmental decentralized services, CBOs, NGOs, authorities, public utilities, private sector members and, often left unnoticed, donors.

Use of data of volume generation of Fecal Sludge

Accurate method for estimation of generation of volume of fecal sludge in the city should be established and the data of volume of FS generation must be used for designing emptying service like size and number of vacutug, size of treatment plant or disposal and proposition for resource recovery for reuse.

Enforcement of scheduled de-sludging of septic tanks

Scheduled desludging or block-desludging can be done by the city authority. This will help to desludge timely and City authority can get a huge amount of revenue. Awareness and political will must be available or created at various government levels to attain sustained improvements in FS management. Municipal or entrepreneurial bodies must be in place or developed to provide effective FS collection, haulage and treatment services, and urban dwellers must feel the need and be willing and able to pay for improved excreta disposal.

Local manufacturer of emptying device

MAWTS, one sister concern of Caritas, the only manufacturer of vacutug in Bangladesh based in Dhaka. The cost of vacutugs and spare parts are so high. Local level workshop can be trained so that they can manufacture it locally with low cost. Then it will be in affordable limits of the cities.

Laboratory upgrading

Most of the people or organization working in southern Bangladesh are dependent on Khulna University of Engineering and Technology (KUET) for testing different types of parameter. The environment laboratory of KUET is not capable for laboratory analysis of FS. So, the existing laboratory cab be upgraded so that they can test the FS characteristics.

Addressing Health and Safety issues

The issue on health and safety to internalized as the most important factor in fecal sludge management. In emptying operation of faecal sludge, job safety would be improved by better protective equipment which includes:

– Personal protective equipment: hardhat, face/eye protection, boots, and gloves;

– Disinfectants, barriers, sorbents and bags for cleaning up spilled materials.

Proper guidelines as per local context are necessary. Training to the operators is necessary. Municipal authority can give certificate to the operators both manual and mechanical ensuring all they have received proper training and all the safety gears. Regular follow up can make them use of PPE. Occupational health and safety of the emptier is a critical issue while emptying septic tank.

Research on reuse of treated FS

There are scope for using as co-compost, bio-gas, electricity, biofuel, fertilizer for growing plankton which can be used as fish-feed. Recently, Bangladesh Agricultural Research Institute (BARI) and Fisheries and Marine Resource Technology department of Khulna University have started the research on use of FS in agriculture and aquaculture respectively and the result is encouraging. Intensive research is needed to establish for reuse of FS in these sectors. There should be resource recovery like biogas or co-compost. So, the private entrepreneur can be attracted in business perspective.

Environmental considerations for sustainable FSM

In all the components of FSM value chain environment should be considered in priority basis. Use of improved toilets to be ensured. The septic tank cannot be connected with drain which pollutes the environment. Manual emptiers cannot dispose fecal sludge without designated site. Mechanical emptiers also cannot dispose in drain. The treatment plant site to be selected in such a place that environment must not polluted. Environmental Impact Assessment can be done for design a new treatment plant.

5.3 Conclusions

Problems on different components have been determined and possible suggestions were discussed. Finally, proposals were given for the improvement of each component of fecal sludge management. Improvement of Toilet, upgradation of containment, small and appropriate devices for emptying services, simple and easier treatment technology, market based FSM services, social awareness raising, etc. have been recommended.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 General

The thesis entitled "A Comparative Study on Fecal Sludge Management in Three Municipalities of Bangladesh'' was conducted in three selected municipalities namely Khulna City Corporation, Kushtia Pourashava and Jhenaidah Pourashava. The objectives of this study were (a) To study the volume of fecal sludge generation and its characterization for the study areas; (b) To investigate the existing fecal sludge emptying process (both manual and mechanical) in the study areas; and (c) To inspect the ongoing treatment and disposal practices and to explore strategies for improvement of fecal sludge management (FSM) in the study areas. The conclusions for fecal sludge management in the studied three municipalities are summarized in section 6.2 and some recommendations are listed in section 6.3.

6.2 Conclusions

First objective was to study the volume of fecal sludge generation and its characteristics in Khulna, Kushtia and Jhenaidah municipalities. In Khulna, fecal sludge generation was estimated to be around 721213 m^3/year and 710000 m^3/year on the basis of theoretical calculations and practical field survey, respectively. In Kushtia municipality, the fecal sludge volume was found to be 104,581 and 109,527 m^3/year, respectively for practical and theoretical estimations. Volumes of faecal sludge in Jhenaidah were 58,705 and 68,078 m^3/year from field survey and theoretical estimation. These data would help to calculate the design of vehicle requirements for mechanical emptying, manpower for operating the services, design the size of treatment plants as well as the projection of resource recovery.

Experiments have been performed for sixteen wastewater quality parameters for each fecal sludge (FS) sample. Parameters have been considered for the characterization of FS which include: total solids, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), nutrients, pathogens, etc. In all three municipalities pH was found to be slightly higher than 7.0

which indicates alkaline nature of collected FS samples. BOD_5 was found to be varying in the range of 834-1662 mg/L. Thus, reduction of BOD through FS treatment plant is a big challenge. COD was found to be varied from 7600 mg/L to 9600 mg/L. Total solids in three municipal areas were found between 3% to 6% and almost similar in both pit toilets and septic tanks. Total Coliform (TC) and Escherichia Coliform (E.Coli.) were found to be 152000-444000 N/100ml and 110000-390000 N/100ml, respectively. Sludge volume index (SVI) was found to be 19-33 ml/g. In three cities, Fe, NO_3 and PO_4 were found to be varied between 19-48 mg/L, 138-390 mg/L and 105-2808 mg/L, respectively. There is currently a lack of detailed information on the characteristics of FS. However, these results would help for performance monitoring of the treatment plant, analysis of co-compost and crops using FS.

Second objective was to investigate the existing fecal sludge emptying process (both manual and mechanical) in the above three municipalities. In the study areas, more than 85% of households practice unsafe FS emptying and conveyance. For emptying of septic tanks/pits, sweepers are largely used in all the areas. 81%, 34% and 98% of total emptying in Khulna, Kushtia and Jhenaidah have been found emptied by sweepers. In Khulna, Kushtia and Jhenaidah, the population of sweeper community are 786, 270 and 441, respectively. There are 248 families in Khulna where 171 are engaged in manual emptying. In Kushtia only 22 and in Jhenaidah only 25 are engaged with manual emptying. Monthly income per family in Khulna, Kushtia and Jhenaidah are BDT 4287, 2716 and 2000, respectively. These numbers of sweepers are not enough to provide services against the total population of the municipalities. However, a combination of sweepers and mechanical cleaning is predominant in Kushtia Paurashava. There are two 4000 liters capacity vacutugs in Khulna City Corporation. But still they have been providing service with manual boggies. Community Development Committee (CDC) are operating three vacutugs of 1000 liters each. Kushtia Municipality started vacutug-based desludging operation for emptying of septic-tanks/pit-latrines from 2004 with a 500 litre capacity small vacutug. Now, the municipality owns 4 vacutugs with capacity of 500, 1000, 2000, and 4000 litres. The municipality is now serving 3-4 emptying services a day. Jhenaidah municipality possesses 700 Liter, 1000 Liter and 2000 Liter vacutugs. The mechanical emptying in these three cities are only 1%. In all three municipalities, development partners and the Government of Bangladesh have provided logistic support to the local authorities for emptying, but due to lack of properly addressing the entire value chain of FSM, the collected sludge is directly or indirectly being disposed into waterbodies. People perception is positive regarding the necessity of emptying mechanically, but due to lack of service and information, demand of service hasn't been increased. Now the municipalities are aware enough with the support of development partners to address emptying services properly.

Third objective was to inspect the ongoing treatment and disposal practices and to explore strategies for improvement of fecal sludge management (FSM) in the study areas. Since, there are no proper disposal site in Khulna city, most of the sludge is dumped at undesignated places. There are four Decentralized Wastewater Treatment System (DEWATS) in Khulna for serving only four buildings of the concerned area with 80 latrines of 680 peoples of 165 families. The water quality of the DEWATS of Khulna have been tested in the laboratory. BOD_5 in the effluent water was found to be laying within the acceptable limit of 40 mg/L for disposal into inland water bodies (ECR'97). Kushtia Municipality jointly established a pilot composting plant at Baradi in 2008. The municipality started co-composting since January 2013. Maximum feed is 49000 liters per bed for 15 days to dry and this treatment plant has the monthly capacity of treating 50,000-60,000 liters of sludge. Jhenaidah has virtually no services for safe sludge management, not even from the Paurashava. But with support from the Department of Public Health Engineering (DPHE), a treatment plant had been constructed in 2012. The existing treatment plant is constructed wetland (CW) system which can operate at 90 m^3/week based on loading of 0.3 m^3/day with 2-3 days Hydraulic Retention Time (HRT), and resting period of 2-3 days before receiving new loads. The estimated capacity of this plant is about 4,700 m3/year. As there is no unit for percolate treatment, effluent is directly discharged into nearby canal. In Khulna, there is a biogas plant at Khalishpur Bihari colony using the community toilets. In Kushtia, co-compost is being produced and two action researches have been launched for the use of FS in agriculture with Bangladesh Agricultural Research Institute (BARI) and in aquaculture with Department of Fisheries and Marine Resource Technology (FMRT, Khulna University). In Jheanidah, there is no example of reuse of fecal sludge. First component of FSM value chain is toilet which has the coverage of 99%, 99% and 98%, respectively for Khulna, Kushtia and Jhenaidah without considering its hygienic conditions. The second component is containment. In Khulna and Kushtia, 84% and 68% of households, respectively have septic tanks connected to drains or surface water. In emptying, only 1% is being done mechanically. In Kushtia, 4% of FS disposal was found to be in safe manner while in other municipalities, safe disposal was less than 1%. Different organizations came and worked alone or with municipality as piece mil basis. The vacutugs and treatment plants have been constructed, but no capacity building of the municipality has been initiated. Entire value chain of FSM has not yet been addressed properly. However, this is a good symptom that these three municipalities have initiated to address all the components of value chain of fecal sludge management. There are scopes of improvement and the municipalities should come forward to know the facts and address those properly.

6.3 Recommendations for Improvement of FSM in Study Areas

This study will provide a clear vision on the field performance of the existing fecal sludge management practice in Khulna, Kushtia and Jhenaidah municipalities. Health and safety aspects of manual and mechanical emptier are recommended for better life of the emptier. Technical problems in operation and maintenance, socio-economic acceptance, impact on livelihood of sweepers and any possible adverse impacts on surrounding environment has been addressed. The final goal is to suggest modifications of existing FSM systems which would suit the local urban condition of Bangladesh for its long-term sustainability. This study would provide details of improvement strategies with justification and supporting evidences.

Fecal sludge management (or FSM) may not be a typical dinner party conversation, but in the development sphere, the potential and challenges of FSM are hot topics. (Source: Fecal Sludge Management in India: Finding Sustainable Solutions). Thus, following recommendations are suggested with a view to improve the present status on fecal sludge management in the study areas:

- Toilet upgrading in terms of water seal, Y-junction and proper maintenance
- Up-gradation of Containment specially for septic tank
- Training and registration of the Manual Emptiers
- Small mechanical device to be introduced
- Enforcement of scheduled de-sludging of septic tanks/pits
- Secondary Transfer Station can minimize cost and time.

- Treatment Process should be simple and easy operation
- Call center to streamline the whole process of emptying of a city
- FSM should be a Market Based Solution
- Social Awareness are essentially required
- Local manufacturer of vacutugs can minimise the higher cost
- KUET Environmental Engineering Laboratory can be upgraded for laboratory analysis of FS of these three cities as well as the region
- Addressing of Health and Safety issues in emptying and treatment process
- Research on Reuse of treated FS to be done rigorously
- Environmental considerations for sustainable Fecal Sludge Management are very much needed

Amongst all of the excitement in introducing these products, there is a need to step back and assess what the community actually needs and how to ensure its being met through sustainable solutions. This outlook means that inventors and engineers should understand the community before developing a new FSM technology or at least understand that it may not be the best fit for resource poor communities in Bangladesh. In other words, there is no one size fits all solution to FSM, and the communities who need it most may be the most difficult to fit. In a nutshell, the challenge and goal to be met is to ensure that all FS generated in the urban environment is discharged at designated storage or treatment sites, that illegally and indiscriminately dumped untreated FS is stopped and that FS is subjected to adequate treatment prior to agricultural use or landfilling. It is being recommended to do intensive research on different and innovative technology of empting devices, performance of the treatment plants, laboratory analysis and reuse of fecal sludge.

According to FAO- "Sustainable Development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. The environmental friendly resource represent; environmentally non-degrading, technically appropriate, economically viable and socially acceptable”. Thus, further research is essential for carry out sustainable fecal sludge management in Bangladesh.

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Test Report on Fecal Sludge Characteristics (Siddikia Madrasha Hostel Septic Tank, Ward 18, Khulna City Corporation)

Sl. No.	Water Quality Parameters	Units	*Standard Methods (SM) of Analysis	Test Results	Limits for Disposal in Water Bodies (ECR'97, Bangladesh)
1.	pH	--	SM 4500-H^+ B	7.44	--
2.	Biochemical Oxygen Demand (BOD_5)	mg/l	SM 5210 B	1434	40
3.	Chemical Oxygen Demand (COD)	mg/l	SM 5220 C	9600	--
4.	Total Solids (TS)	mg/l	SM 2540 B	44560	--
5.	Total Suspended Solids (TSS)	mg/l	SM 2540 D	29650	100
6.	Total Volatile Solids (TVS)	mg/l	SM 2540 E	27980	--
7.	Volatile Suspended Solids (VSS)	mg/l	SM 2540 E	22240	--
8.	Total Coliform (TC)	N/100ml	SM 9222 B	444000	--
9.	Escherichia Coliform (E.Coli.)	N/100ml	SM 9222 D	390000	1000 (Fecal Coliform)
10.	Sludge Volume Index (SVI)	ml/gm	SM 2710 D	33	--
11.	Iron (Fe)	mg/l	SM 3500-Fe B	23	--
12.	Nitrate (NO_3)	mg/l	SM 4500-NO_3^- E	138	250
13.	Phosphate (PO_4)	mg/l	SM 4500-P E	2808	35
14.	Electrical Conductivity (EC)	mS/cm	SM 2510 B	2.08	--
15.	Temperature	°C	SM 2550 B	20.1	30
16.	Total Alkalinity (as $CaCO_3$)	mg/l	SM 2320 B	4500	--

**Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF)*

Test Report on Fecal Sludge Characteristics (Raligate Household Pit Latrine, Ward No. 1, Khulna City Corporation)

Sl. No.	Water Quality Parameters	Units	*Standard Methods (SM) of Analysis	Test Results	Limits for Disposal in Water Bodies (ECR'97, Bangladesh)
1.	pH	--	SM 4500-H^+ B	7.19	--
2.	Biochemical Oxygen Demand (BOD_5)	mg/l	SM 5210 B	1662	40
3.	Chemical Oxygen Demand (COD)	mg/l	SM 5220 C	9200	--
4.	Total Solids (TS)	mg/l	SM 2540 B	38920	--
5.	Total Suspended Solids (TSS)	mg/l	SM 2540 D	30060	100
6.	Total Volatile Solids (TVS)	mg/l	SM 2540 E	19460	--
7.	Volatile Suspended Solids (VSS)	mg/l	SM 2540 E	22545	--
8.	Total Coliform (TC)	N/100ml	SM 9222 B	168000	--
9.	Escherichia Coliform (E.Coli.)	N/100ml	SM 9222 D	117000	1000 (Fecal Coliform)
10.	Sludge Volume Index (SVI)	ml/gm	SM 2710 D	26	--
11.	Iron (Fe)	mg/l	SM 3500-Fe B	48	--
12.	Nitrate (NO_3)	mg/l	SM 4500-NO_3^- E	270	250
13.	Phosphate (PO_4)	mg/l	SM 4500-P E	2184	35
14.	Electrical Conductivity (EC)	mS/cm	SM 2510 B	3.66	--
15.	Temperature	°C	SM 2550 B	24	30
16.	Total Alkalinity (as $CaCO_3$)	mg/l	SM 2320 B	10500	--

**Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF)*

Test Report on Fecal Sludge Characteristics (Sweeper Colony Septic Tank, Ward No. 7, Jhenaidah Municipality)

Sl. No.	Water Quality Parameters	Units	*Standard Methods (SM) of Analysis	Test Results	Limits for Disposal in Water Bodies (ECR'97, Bangladesh)
1.	pH	--	SM 4500-H^+ B	8.13	--
2.	Biochemical Oxygen Demand (BOD_5)	mg/l	SM 5210 B	819	40
3.	Chemical Oxygen Demand (COD)	mg/l	SM 5220 C	8800	--
4.	Total Solids (TS)	mg/l	SM 2540 B	41380	--
5.	Total Suspended Solids (TSS)	mg/l	SM 2540 D	39540	100
6.	Total Volatile Solids (TVS)	mg/l	SM 2540 E	32630	--
7.	Volatile Suspended Solids (VSS)	mg/l	SM 2540 E	29580	--
8.	Total Coliform (TC)	N/100ml	SM 9222 B	231000	--
9.	Escherichia Coliform (E.Coli.)	N/100ml	SM 9222 D	196000	1000 (Fecal Coliform)
10.	Sludge Volume Index (SVI)	ml/gm	SM 2710 D	25	--
11.	Iron (Fe)	mg/l	SM 3500-Fe B	39	--
12.	Nitrate (NO_3)	mg/l	SM 4500-NO_3^- E	198	250
13.	Phosphate (PO_4)	mg/l	SM 4500-P E	105	35
14.	Electrical Conductivity (EC)	mS/cm	SM 2510 B	3.78	--
15.	Temperature	°C	SM 2550 B	29.6	30
16.	Total Alkalinity (as $CaCO_3$)	mg/l	SM 2320 B	10500	--

**Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF)*

Test Report on Fecal Sludge Characteristics (Ayesha Nurse Septic Tank, Ward No. 4, Jhenaidah Municipality)

Sl. No.	Water Quality Parameters	Units	*Standard Methods (SM) of Analysis	Test Results	Limits for Disposal in Water Bodies (ECR'97, Bangladesh)
1.	pH	--	SM 4500-H^+ B	8.14	--
2.	Biochemical Oxygen Demand (BOD_5)	mg/l	SM 5210 B	936	40
3.	Chemical Oxygen Demand (COD)	mg/l	SM 5220 C	8800	--
4.	Total Solids (TS)	mg/l	SM 2540 B	45640	--
5.	Total Suspended Solids (TSS)	mg/l	SM 2540 D	41600	100
6.	Total Volatile Solids (TVS)	mg/l	SM 2540 E	33380	--
7.	Volatile Suspended Solids (VSS)	mg/l	SM 2540 E	30960	--
8.	Total Coliform (TC)	N/100ml	SM 9222 B	170000	--
9.	Escherichia Coliform (E.Coli.)	N/100ml	SM 9222 D	110000	1000 (Fecal Coliform)
10.	Sludge Volume Index (SVI)	ml/gm	SM 2710 D	23	--
11.	Iron (Fe)	mg/l	SM 3500-Fe B	30	--
12.	Nitrate (NO_3)	mg/l	SM 4500-NO_3^- E	390	250
13.	Phosphate (PO_4)	mg/l	SM 4500-P E	153	35
14.	Electrical Conductivity (EC)	mS/cm	SM 2510 B	4.33	--
15.	Temperature	°C	SM 2550 B	30	30
16.	Total Alkalinity (as $CaCO_3$)	mg/l	SM 2320 B	9500	--

**Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF)*

Test Report on Fecal Sludge Characteristics (Sweeper Colony Pit Latrine, Ward No. 2, Jhenaidah Municipality)

Sl. No.	Water Quality Parameters	Units	*Standard Methods (SM) of Analysis	Test Results	Limits for Disposal in Water Bodies (ECR'97, Bangladesh)
1.	pH	--	SM 4500-H^+ B	8.19	--
2.	Biochemical Oxygen Demand (BOD_5)	mg/l	SM 5210 B	1110	40
3.	Chemical Oxygen Demand (COD)	mg/l	SM 5220 C	8400	--
4.	Total Solids (TS)	mg/l	SM 2540 B	58890	--
5.	Total Suspended Solids (TSS)	mg/l	SM 2540 D	56710	100
6.	Total Volatile Solids (TVS)	mg/l	SM 2540 E	47360	--
7.	Volatile Suspended Solids (VSS)	mg/l	SM 2540 E	41250	--
8.	Total Coliform (TC)	N/100ml	SM 9222 B	190000	--
9.	Escherichia Coliform (E.Coli.)	N/100ml	SM 9222 D	135000	1000 (Fecal Coliform)
10.	Sludge Volume Index (SVI)	ml/gm	SM 2710 D	18	--
11.	Iron (Fe)	mg/l	SM 3500-Fe B	19	--
12.	Nitrate (NO_3)	mg/l	SM 4500-NO_3^- E	258	250
13.	Phosphate (PO_4)	mg/l	SM 4500-P E	171	35
14.	Electrical Conductivity (EC)	mS/cm	SM 2510 B	3.40	--
15.	Temperature	°C	SM 2550 B	29.8	30
16.	Total Alkalinity (as $CaCO_3$)	mg/l	SM 2320 B	10500	--

**Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF)*

Test Report on Fecal Sludge Characteristics (Fazlur Rahman, Thana Para Septic Tank, Ward No. 2, Kushtia Municipality)

Sl. No.	Water Quality Parameters	Units	*Standard Methods (SM) of Analysis	Test Results	Limits for Disposal in Water Bodies (ECR'97, Bangladesh)
1.	pH	--	SM 4500-H^+ B	8.09	--
2.	Biochemical Oxygen Demand (BOD_5)	mg/l	SM 5210 B	1422	40
3.	Chemical Oxygen Demand (COD)	mg/l	SM 5220 C	8400	--
4.	Total Solids (TS)	mg/l	SM 2540 B	52200	--
5.	Total Suspended Solids (TSS)	mg/l	SM 2540 D	49360	100
6.	Total Volatile Solids (TVS)	mg/l	SM 2540 E	44910	--
7.	Volatile Suspended Solids (VSS)	mg/l	SM 2540 E	39170	--
8.	Total Coliform (TC)	N/100ml	SM 9222 B	230000	--
9.	Escherichia Coliform (E.Coli.)	N/100ml	SM 9222 D	170000	1000 (Fecal Coliform)
10.	Sludge Volume Index (SVI)	ml/gm	SM 2710 D	20	--
11.	Iron (Fe)	mg/l	SM 3500-Fe B	27	--
12.	Nitrate (NO_3)	mg/l	SM 4500-NO_3^- E	168	250
13.	Phosphate (PO_4)	mg/l	SM 4500-P E	1527	35
14.	Electrical Conductivity (EC)	mS/cm	SM 2510 B	4.90	--
15.	Temperature	°C	SM 2550 B	30	30
16.	Total Alkalinity (as $CaCO_3$)	mg/l	SM 2320 B	11000	--

**Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF)*

Test Report on Fecal Sludge Characteristics (Mr. Jhontu, Aruapara Pit Latrine, Ward No. 9, Kushtia Municipality)

Sl. No.	Water Quality Parameters	Units	*Standard Methods (SM) of Analysis	Test Results	Limits for Disposal in Water Bodies (ECR'97, Bangladesh)
1.	pH	--	SM 4500-H^+ B	8.19	--
2.	Biochemical Oxygen Demand (BOD_5)	mg/l	SM 5210 B	834	40
3.	Chemical Oxygen Demand (COD)	mg/l	SM 5220 C	7600	--
4.	Total Solids (TS)	mg/l	SM 2540 B	38400	--
5.	Total Suspended Solids (TSS)	mg/l	SM 2540 D	35360	100
6.	Total Volatile Solids (TVS)	mg/l	SM 2540 E	31980	--
7.	Volatile Suspended Solids (VSS)	mg/l	SM 2540 E	27220	--
8.	Total Coliform (TC)	N/100ml	SM 9222 B	165000	--
9.	Escherichia Coliform (E.Coli.)	N/100ml	SM 9222 D	124000	1000 (Fecal Coliform)
10.	Sludge Volume Index (SVI)	ml/gm	SM 2710 D	27	--
11.	Iron (Fe)	mg/l	SM 3500-Fe B	36	--
12.	Nitrate (NO_3)	mg/l	SM 4500-NO_3^- E	246	250
13.	Phosphate (PO_4)	mg/l	SM 4500-P E	195	35
14.	Electrical Conductivity (EC)	mS/cm	SM 2510 B	5.96	--
15.	Temperature	°C	SM 2550 B	29.7	30
16.	Total Alkalinity (as $CaCO_3$)	mg/l	SM 2320 B	9500	--

**Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF)*

Test Report on Fecal Sludge Characteristics (Housing Colony Septic Tank, Ward No. 6, Kushtia Municipality)

Sl. No.	Water Quality Parameters	Units	*Standard Methods (SM) of Analysis	Test Results	Limits for Disposal in Water Bodies (ECR'97, Bangladesh)
1.	pH	--	SM 4500-H^+ B	8.16	--
2.	Biochemical Oxygen Demand (BOD_5)	mg/l	SM 5210 B	912	40
3.	Chemical Oxygen Demand (COD)	mg/l	SM 5220 C	8800	--
4.	Total Solids (TS)	mg/l	SM 2540 B	54410	--
5.	Total Suspended Solids (TSS)	mg/l	SM 2540 D	52730	100
6.	Total Volatile Solids (TVS)	mg/l	SM 2540 E	47570	--
7.	Volatile Suspended Solids (VSS)	mg/l	SM 2540 E	39030	--
8.	Total Coliform (TC)	N/100ml	SM 9222 B	152000	--
9.	Escherichia Coliform (E.Coli.)	N/100ml	SM 9222 D	121000	1000 (Fecal Coliform)
10.	Sludge Volume Index (SVI)	ml/gm	SM 2710 D	19	--
11.	Iron (Fe)	mg/l	SM 3500-Fe B	30	--
12.	Nitrate (NO_3)	mg/l	SM 4500-NO_3^- E	270	250
13.	Phosphate (PO_4)	mg/l	SM 4500-P E	147	35
14.	Electrical Conductivity (EC)	mS/cm	SM 2510 B	3.66	--
15.	Temperature	°C	SM 2550 B	29.8	30
16.	Total Alkalinity (as $CaCO_3$)	mg/l	SM 2320 B	14000	--

**Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF)*